THE INTRODUCTION OF CYANIDING IN NEW ZEALAND: A CASE STUDY IN THE ROLE OF TECHNOLOGY IN HISTORY

Sybil M. Jack

This article explores the factors influencing entrepreneurial decision-making about the introduction of new technological processes in the gold mining companies of nineteenth century New Zealand. It attempts to estimate the significance of scientific discoveries to technological advance, and the influence of government, economic circumstances and patent laws. In this way, it seeks to explain the retardation of the introduction of cyaniding as a combination of scientific and expert doubt about the effects of cyanide, the entrepreneurial problem of distinguishing the one young swan among the ducklings, and the pricing policy of the patent owners. It indicates briefly the effects that the introduction of cyaniding had on the structure of the gold mining industry.

Keywords: nineteenth century history, New Zealand, science and technology, gold mining, metallurgy, cyaniding

INTRODUCTION

The microchip has once again brought to the fore the debate about the role of technology in society and the changes which new technologies precipitate in the lives of those involved. In these discussions, which generally mark moments of concentrated technological shift, historians are expected to provide 'lessons from the past', while at the same time doubt is expressed as to the relevance of such insights since 'this time it is different'. The quandary of whether it is appropriate to apply to developing societies practices drawn from the recent past of capitalist societies, is even more acute.[1]

The nineteenth century on the whole took for granted the idea that knowledge, applied as innovation to industry, could produce wealth and ultimately change. It is, therefore, undoubtedly wrong to attribute to Marx the cruder forms of technological determinism which characterise certain later Marxists. Nineteenth century debate was conducted on a level singularly far removed from the nitty gritty of actual cases. Marx's celebrated aphorism about the handmill and feudal society suggests that precise chronological coincidence was not critical to the argument.[2]

Some loss of faith in the underlying tenet has characterised twentieth century attempts to determine the precise relationship among technology, economy, and society and establish parameters for its study.[3] It has remained, however, a subject which characteristically produced more heat than light. The idea that a particular sociological context was critical to the development of a situation in which the constant modification of technology was accepted as the norm[4] was easier to formulate than isolating the relevant characteristics proved to be. The precise relationship between technological innovation and economic success has still not been clearly established. Habakkuk argued a skilful case for the significance of the labour supply to the rate of technological innovation, but in doing so he concentrated on land and machinery, largely ignoring mining.[5]

The movement for counterfactualism, moreover, appeared to reduce to comparative insignificance the role of technology, as it argued that the significance of the introduction of the railway had been grossly over-estimated in economic terms.[6] Part of the problem, however, is created by the difficulty of isolating the effects of a specific invention. When this has been attempted in an effort to study the interaction of science and technology, attention has tended to be focussed on the mechanical side of invention.[7] The particular problems of metallurgy have been downplayed.

General ideas on the relationship between risk and technological innovation have been generated but not widely accepted.[8] All of this creates certain difficulties for anyone seeking to relate an in-depth study of a particular example of innovation to any general hypothesis.[9] Some queries may seem more significant to the investigator than others, but they are clearly not the only possible areas of interest. Are science and technology, for example, separate bodies of thought? If they are, to what extent do they overlap; and if they do, in what ways do they interact?[10] In a different context Simmons has suggested that historians of technology should investigate the effects of innovations in terms of:

> . . . what they cost to build and run as compared with their predecessors, their productivity, the effects they had on employment, the side effects they sometimes entailed in local or national politics and the relations between states.[11]

THE CASE STUDY

There are a number of reasons which make the introduction of cyaniding in New Zealand a particularly suitable case study for some of these points. Apart from other considerations, any study in which the potential number of variables is reduced must clarify the picture.

Entrepreneurs in the past adopted certain technologies or maintained older systems in the face of apparently preferable alternatives for a variety of reasons. In the case of gold mining, however, some of the variables did not apply. Potential fluctuations in the market for the end product were not a consideration which producers needed seriously to consider. At a virtually fixed price per ounce the market would absorb all that could be produced. In the nineteenth century, fluctuations in the output of gold do not seem to have been primarily influenced by economic factors.[12] The case would seem to allow investigation of the relationship of science and technology, the factors influencing entrepreneurial decision-making (including the contentious issue of the influence of patent law), the effects on employment and the involvement of political factors.

THE PROBLEM

The mine manager wanted a method of chemical extraction that was as simple as possible, foolproof (since highly skilled labour was expensive) and, above all, cheap. The profit of a gold mine represented output less costs, and costs could vary enormously. While reefs containing a high percentage of free gold were economic, even if gold was lost in the tailings, complicated 'refractory' ores in which the gold was awkwardly combined in a matrix containing silver, copper, arsenic and antimony ores and especially sulphides could be effectively unpayable even where laboratory assay tests revealed a high gold content.

A commercially viable process had to be cheap enough to leave a profit which might mean that 'wasteful' systems were more profitable than 'efficient' systems. A profitable yield from a company's point of view related primarily to output as measured by unit of time rather than output per ton of ore processed, although that was also an element in the equation. Nevertheless, a slow throughput of ore using elaborate machinery and expensive fluxes might well produce a lower return in terms of either fixed or working capital (or both) than a fast throughput which extracted less per ton but more in a given period of time. The use of more efficient processes had to be calculated in terms of the percentage of additional yield in relation to the new or additional costs and the level of wages of the employees involved. The initial capital cost might also be an absolute bar. If an entirely new system was to be introduced, the new costs, if they could be met at all, represented the whole cost of the system, less any resale value the old might have. The problems of selecting a technology were particularly acute in gold working because the wide variety of conditions in which the ore was found rendered it unlikely that a single solution appropriate to all cases could be found.

By the early 1880s gold mining in New Zealand was approaching crisis-point. The quartz ores were proving to be extremely complex and yielded little or nothing using the common commercial methods. The existing practice suitable for 'free' coarse gold was to hand pick and break down the ore until it was small enough to be fed into the stamps, where it was wet-crushed. The ore might then be partly amalgamated in the stamps with mercury and passed out over mercury tables or blanketings from which the gold was periodically recovered. When complex ores were treated, however, the mercury often became 'floured' and useless while even free gold, if it was very fine, might be carried away in the water-flow. Roasting the ore, or roasting the concentrates before amalgamation, might remove the sulphur, but left the base metals as oxides to 'waste' the mercury. Besides, the additional costs involved (primarily in fuel) made it worthwhile only with rich ores or where fuel was exceptionally cheap.

In consequence, mining activity was declining. New Zealand sought new technologies overseas, but the alternative techniques brought back from such trips, or the overseas expert brought in, proved ineffective. A man who was "everything that could be desired" when dealing with familiar ores, nonetheless had difficulties with new ores.[13] Similarly, a machine such as the Otis ore crusher, well suited to friable ores, might be useless on the harder New Zealand material.

THE ROLE OF GOVERNMENT

For New Zealand, the crisis was all the more serious because in the young colony gold and coal were the only minerals discovered in significant payable quantities. Since freezing works for the export of meat and dairy products were in their infancy, the government was heavily dependent on gold for its exports and also to attract much needed capital. It, therefore, did all in its power to promote the industry both by encouraging the widest possible dissemination of information and by directly undertaking the provision of essential material infrastructure. The construction of roads and water-races for the mining communities and the sale of water were frequently directly undertaken by the Department of Mines.

In 1882, as the colony's economic depression deepened, the government also appointed its first Mining Inspector, H.A. Gordon, who was encouraged to produce reports on new experiments and machinery, and cost-evaluations of metallurgical practices in various of the New Zealand mines. Gordon was an experienced and travelled man. By careful perusal of the scientific and technical journals from various parts of the world, he attempted both to keep himself up to date and to inform others. His influence on New Zealand mining, however, was not confined to his Reports, since it was also his job to visit and inspect as many of the mining fields as was practicable and to co-ordinate the activities of the schools of mines. In addition, in 1889 he produced the standard handbook for those who wanted to qualify as mine managers in New Zealand under the Mining Act of 1886, a handbook he subsequently updated in 1894 and 1906.[14] His influence was thus considerable but although he was conscientious and cautious, his judgement was by no means impeccable. He wrote with guarded enthusiasm of various machines and processes which were not subsequently successful while he was initially extremely reluctant to recommend the cyanide process.

Certain of Gordon's enthusiasms cast considerable light on the type of development likely to attract mining money. One was his attempt to promote improved ore-crushing processes. The primitive stamp battery had had any number of drawbacks. Over the years improvements in design and materials had made the more modern stamp battery a vastly superior machine in which the weight of the heads, the length of drop, the number of drops per minute, the order of stamp fall, the shape and size of the mortar box, could all be separately regulated to suit the particular ore and the process for which it was being prepared. Nevertheless, it still consumed a considerable amount of power and tended to reduce the ore to proportions so fine that 'slimes' which were hard to treat were produced. No matter how coarse the mesh, the ore did not necessarily pass through the moment it was sufficiently fine to do so, but remained in the stamp box and was (unnecessarily) further pulverised. With complex ores the disadvantages were believed to be even greater as the ore was coated or embedded in such a way that the gold would not come into contact with the mercury and so amalgamation did not take place.

Gordon believed that some form of roller system in which gradual reduction of the ore might be combined with its immediate sifting as soon as the required fineness was achieved (a principle then being introduced very effectively in flour milling) might be the answer. In practice, however, it was discovered that these machines tended to wear unevenly and required frequent expensive replacement. Mill men seemed less concerned with the cost of power than the cost of replacement and the dominance of the stamp mill continued.

Gordon also promoted the La Monte furnace, a water-jacketed furnace designed for silver and the production of concentrates. On his travels in Europe and America he had seen several plants, not directly connected with any one mine, which made a handsome profit by purchasing concentrates and treating them to produce refined gold. Gordon was convinced that New Zealand resources could best be organised along these lines. What small, individual mines run by 'practical' miners could not hope to achieve might be done on a large scale by careful use of fluxes in a smelting or chlorinating works. Alternatively, it might be sensible to sell New Zealand concentrates overseas.[15]

EARLY AND UNSUCCESSFUL ATTEMPTS AT AN IMPROVED TECHNOLOGY

The problem in the 1880s was unquestionably a technical one. There was no immediate shortage of labour and labour costs were rarely the significant factor which turned profit into loss. At the beginning of the period the London market would generally put up capital for companies which could afford a reasonable 'puff'. The refractory ores, however, did not yield the gold they contained by existing means at a profitable rate. Attention was, therefore, focussed on new forms of technology and the absence of any clear lead made it a period of highly varied experimentation and technical controversy. The problem was aggravated by the scarcity and consequent high cost of fuel in many areas.

Initially some form of chlorination process seemed the most promising approach for New Zealand ores. Chlorination methods were fairly well established outside New Zealand and Gordon had seen the Plattner process, which was common in California. The formula involved a very careful roasting of the ore to expel the sulphur and, by the addition of salt, as far as possible to prevent or reduce the tendency of the other metals present to form chlorides. The oxidised ore, moistened with water, was put in a vat with a false bottom and chlorine introduced between the true and false bottom so that the gold eventually became a soluble chloride which could be run off and precipitated. It was an expensive process but one highly successful at such places as Sandhurst in Victoria and Mount Morgan in Queensland (where it was still being used in the twentieth century),[16] but it did not suit ores which contained lead or silver as well as gold. Gordon hoped, however, that further modifications of the system by the use of additional fluxes, a difference in furnace shape or method of introducing the chlorine (such as the use of revolving barrels or air pressure or hydraulic pressure) might solve the problem.[17]

Mine managers, following Gordon's tentative advice, introduced La Monte furnaces at Thames and Karangahake, but serious difficulties arose. The economic failure of the process led to an illuminating dispute between the directors and the inventor. The process was inherently unprofitable on these poorer ores because of the volume and cost of the fluxes and fuel. Labour costs were comparatively insignificant.[18] The government comforted itself with the thought that it had been a "good education" for the miners in distinguishing grades of stone, but for the company it was one more lesson on the risk of untried technologies.[19]

Nevertheless, those mine managers with the resources to do so continued to try improvements on known processes or new devices that might save on energy costs. Thus in 1887, at Skippers Creek, water power available at a distance was utilised by converting the power from two Pelton hurdy-gurdy wheels into electricity which could be conveyed by wire to drive the crushers.[20] This was not strictly 'efficient' (70 h.p. from the wheels became a mere 20 h.p. at the battery), but given ample cheap water supplies it was economically viable. At Karangahake, Railly built a new plant on a chloridising lixiviation principle — the tailings being passed through grinding pans where mercury, salt and copper sulphate were added, the mixture heated to 210° fahrenheit, put through separators, filtered and retorted. It was thought this should recover 90 per cent of the gold. Unfortunately, while the use of sulphate of copper worked satisfactorily in America, where Railly had come from, it did not save the necessary percentage of the gold, and the cost at £ 1.10.0 a ton was too high. The company stopped operating and the plant was sold. Gordon at the time was not convinced that this was the best way and provided a description of what he thought was a similar but better Californian system.[21] New processes in Australia were closely watched, but Gordon dismissed as unoriginal and unsuited to silver-bearing ores the Newberry-Vautin chlorination process which was in use at Mount Morgan. In general, opinion seemed to be that chlorination could be used with such ores only if the silver was first separated, but this multiplied the number of processes involved and raised the cost.

Dry-crushing (ignoring the health hazards involved), roll crushing, more efficient revolving cylinder roasting furnaces which would enable a continuous process to be maintained, and — above all — the merits of concentrating the ore before treatment, were the best suggestions Gordon could offer; but again dry crushing involved prior kiln roasting and an additional consumption of scarce fuel.[22] These constant failures at the local level with ores that had promising assay returns moreover made the attraction of capital from London more difficult as the decade progressed. Patents for new machines and new processes proliferated. Many had apparent promise but most were untried; the manager's choice became more critical and less easily based on firm evidence.

THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

One might argue that scientific studies had retarded rather than advanced the commercial use of cyanide for the extraction of gold. The idea had been proposed — and dismissed. Indeed, William Skey, New Zealand's resident chemical expert, thought in 1876 that "a loss of gold must frequently happen whenever cyanide of potassium is used to assist in the amalgamation of blanketings or other auriferous stuff". In 1877 Dixon had given a paper in NSW in which he detailed experiments with cyanides and ferro-cyanides as solvents for gold and silver in ores containing sulphides of copper, lead, iron and arsenic, but concluded that only a portion of gold could be obtained and thought the line of enquiry not worth pursuing.[23] In the USA patents using cyanide continued to be taken out, but only as an adjunct to amalgamation. One such patent, Simpson's, used it in combination with carbonate of ammonia or chloride of sodium as a solvent, and might have worked, had it been tried and modified in practice as the McArthur-Forrest patent was. Indeed, McArthur and Forrest had not initially recognised the significance of their laboratory test.

Scientists believed that cyanide would dissolve the base metals before the gold and silver and, in Louis Janin's words, "to extract a reasonable percentage of the gold and silver, so great an excess of cyanide is required that the extraction is no longer economical or profitable."[24] The slight knowledge of chemical analysis offered to 'practical' students in the schools of mines in New Zealand and elsewhere was likely, therefore, to direct the potential mine manager's attention away from, rather than towards, the chemical.[25] The 1880s moreover was a period of great upheaval in the world of physical chemistry, in which a new speciality and new forms of exploration were being developed by Van't Hoff and Arrhenius so that the interesting 'frontiers of knowledge' lay elsewhere. British chemists, however, were slow to accept the new approach and the McArthur-Forrest laboratory was working on somewhat old-fashioned lines.[26] The discovery did not at first attract much attention and the first McArthur-Forrest patent was very vague and did not propose any particular manner of operation on a commercial scale. Nevertheless, it was bought up by the Cassel company and it was as a consequence of their attempt to publicise the method that it became commercially viable.

The Cassel company considered South Africa and New Zealand the most likely countries to be interested. When the company's representative arrived in New Zealand in 1889, however, he met with almost universal scepticism. He was able to start using, or experimenting, with the process only by taking a financial interest himself in the Crown Mines company on condition that the company use it.[27] The situation with the Karangahake ores was sufficiently unpromising with all known existing methods, most of which had been tried, to make it a gamble worth taking on those terms.

When the effectiveness of a dilute solution of cyanide had been proved in practice and adopted by a large number of gold-mining companies, scientists were still struggling to explain it in chemical terms. Its discoverers' own explanation was in terms which were not accepted by the majority of scientists. As late as 1897 William Skey had to admit:

> . . . the precise way in which this happy event comes about he does not know. A good deal he knows and he has several plausible looking theories to choose from . . . but certain facts . . . would make any attempt to cyanide gold at all a complete failure.[28]

He further noted that the chemistry was "full of surprises". In common with many mining men, Skey did not honour the scientists. Instead, he spoke of "that miner, to us unknown, who in sheer desperation to make the cyanide solution a workable one, blundered to the discovery of the strong potency of the weak solution." Distinguished scientists at the Appeal hearing in the patents case acknowledged that pure research could not have explained the effect. They argued that:

> . . . cyanide of potassium solution was of such a peculiar nature that . . . no chemist at the present day knows its composition or knows the reactions taking place with it and the knowledge of it is purely experimental.

The question was so complex that it could be solved only by experiment.[29] The admission is interesting, since the direct and immediate relevance of some forms of chemical research to the metallurgical industry was taken very much for granted at the time. Nevertheless, the arguments that emerge reveal how reluctant many of the practical miners were to acknowledge any direct contribution of pure research to the final solution of the problem, and the difficulties which pure science had in offering a clear cut explanation.[30]

THE NEW PROCESS

The Crown mine, Karangahake, thus had the distinction of being the place at which the cyaniding process was first commercially used. The plant erected by the chemist, John McConnell, with Melville and the mine manager, Mr. Napier, was of great significance. Some machines were apparently sent out from Glasgow, but most were locally made.[31] The process was fundamentally very simple and based on the accurate premise that the ore was more easily treated dry.

Dry, finely pulverised ore was put into percolating tanks made of kauri timber four inches thick, nine foot by twelve foot and three foot six deep. These had a six inch thick filter bed of coarse pebbles at the bottom with battens on the top holding on filter cloth. The ore was spread in thin layers and each layer carefully wetted with a watercan containing the cyanide of potassium solution before another was added. This first solution was given 36 hours to dissolve, then there were two more filterings with progressively weaker solutions which were effected as quickly as possible.[32] The bullion then had to be precipitated from the solution and McConnell had some problems with this. It was known that zinc would precipitate the gold, but an effective form of zinc for the purpose was another matter, and a number of attempts were made before zinc shavings were adopted.[33] The precipitation boxes were a connecting series of small barrel-shaped wooden boxes 12 inches high, five inches in diameter.

McConnell was able to demonstrate the effectiveness of this on a number of sample ores from the Hauraki district, including Waihi and Silverton. Significant problems remained, however. Ore which was wet-crushed lacked the porosity necessary to make the process work. As a result, the Crown company experimented with alternative methods to work the slimes — and this was a harder nut to crack. Understandably adapting forms of machinery used in earlier processes, they employed circular vats with vertical shaft arms to agitate the pulp, and then pressed the pulp in a filter with a force pump (modelled on those used in brew houses for pressing liquor from hops), then returned it to a second tank, back to a press, and then to a third tank. It was ingenious, expensive and did not meet with immediate success.[34] The problem remained: the ores were too poor to be properly payable.

THE RETARDATION OF THE INTRODUCTION OF CYANIDE IN NEW ZEALAND

Perhaps the most significant element of this transfer is the time which elapsed between the proof that the system worked and its widespread adoption by New Zealand mining companies. South Africa adopted the process almost at once; why did New Zealand delay? A partial explanation for this was clearly technical — it was rapidly discovered that coarse gold was not effectively treated by cyanide and was still better caught in blankets or on mercury tables. At the same time, however, the problem of treating slimes with poor porosity in a way that allowed oxygen and cyanide effectively to penetrate, was not proving as simple to solve. In South Africa, however, the experimental plant built by Cassel at Natal Spruit near Johannesburg had managed to treat tailings and concentrates in agitation vats with suction filters and the process had spread.[35] It was admitted that cyaniding saved the silver with the gold, which chlorination did not; that cyaniding was cheaper than chlorination, involving no furnaces, no coal and no fluxes; it was admitted that it could treat ores containing lead and zinc. Yet New Zealand was apparently awaiting a yet cheaper process.

Part of the problem related to the labour supply — the importation of skilled labour to handle the machinery could turn a profit into a loss. The primary problem, however, related to the royalty which the Cassel company was charging. Only ore of an assay value of more than £ 2 a ton was a viable proposition. Gordon did some elementary sums for his readers. If the cyanide process extracted 85 per cent of gold and cost 26/5d. (including the royalty), a profit of 7/7d. would accrue. If an existing process extracted only 40 per cent and cost 8/-, the profit was 8/-, that is 5d. more per ton. Moreover, Cassel stipulated that the cyanide must be bought from the company, and if the company could enforce such a monopoly, what was to stop it artifically raising the price? Some early experimental failures with cyanide in the Middle Island made mining men even more cautious.

Instead, the companies continued to experiment with forms of chlorination. The Te Aroha plant, for example, had an advanced American style battery, Frue Vanners and a Howell patent revolving cylinder furnace, plus a Boss plant for ores not suited to crushing, and a White-Howell revolving furnace for chlorination.[36] This was one plant in which labour, understandably, was a key component of the cost and pushed the company into deficit. Within two years the plant was sold to Australia.[37] The Sylvia company, under Dr. Schneidel, had adapted to gold and silver ore the Kayser system being used at the Mount Bischoff tin mine in Tasmania.[38] Gordon, moreover, followed the Victorian government metallurgist, Cosmo-Newbury, in promoting the Luhrig ore dressing and concentrating plant with its continuous processing and mechanical handling so that one New Zealand company ordered one.[39]

ENTREPRENEURSHIP AND RISKY VENTURES

The problems of all the companies is epitomised in those of the Waihi Gold Mining company. Its problems with decision-making about expensive and untried innovations clarify the process by which many companies with less backing and worse gold-mining reefs went to the wall. Waihi's abundant surviving evidence enables us to establish the overt rationale it developed for determining its choice of technology.[40] Mining in the Ohinemuri had started late because it was Maori land and the Maoris were unwilling to part with it, doing so belatedly and reluctantly under government pressure. One of their leaders described the rain that drenched the negotiating day as "the tears that are being shed for Ohinemuri".[41] For a time it seemed that the rape of Ohinemuri might still be avoided as the high yields promised by the "newfangled" assaying method were lost in the inefficient crushing and battery processes. The assay results, however, attracted the attention of one of New Zealand's more successful money managers, Thomas Russell, on a trip back to New Zealand from England.[42]

Russell acquired the Union mine and floated the Waihi Gold Mining company with a London and a New Zealand board. The boards canvassed all available options for treatment in an endeavour to make the commercial yield as near as possible to the incredibly high assay reports.[43] The manager, J.C. Walker, visited the USA on his way back to New Zealand to look at technologies there, and decided on a mixture of UK and USA plant, and, in consideration of problems that the Martha battery had faced with drought, on a steam-driven plant. He also built an assay room, at the time something of a novelty in New Zealand, and employed a German metallurgist.[44] The machinery was most expensive and the initial cost was £ 12,000.[45] It did not prove well chosen. The steam engine proved inadequate for its work, the Globe mills were not only inadequate, but also expensive to run and were soon discarded. The dry crushing roll-crushing system, on which Gordon had placed so much faith, did not gradually reduce the ore to a controlled and uniform size with a saving of power, but wore unevenly and became worse than useless. The combination pan process was similar to that with which Railly had failed at Karangahake and was no more satisfactory. In September 1888, assay results showed that only 65 per cent of the bullion was being recovered. At a cost of £ 1,500 a rotary roasting furnace was added — to no avail.

The local board permitted the manager and engineer to take the plant apart and rebuild it. The decision to use steam alone was revised and it was agreed that water races should be built to drive Pelton wheels. Stamps, with all their known deficiencies, were erected, but dry-crushing was adhered to. Chlorination was also tried. The London board in February 1889 entered into an agreement with the New Zealand Gold Extraction company over the Newberry-Vautin process. This, however, was in time rejected as adding only to the expense and not the yield.[46] On the same score copper sulphate was eliminated from the combination pans.[47] The company began to think of erecting a Frue Vanner to see whether concentrating the ore might indeed help. By 1890, Gordon was officially unimpressed with all this activity, even angry:

> The operations . . . have consisted in nothing but experimenting as to the best class of machinery. For the past twelve months the machinery has been erected and pulled to pieces again and again. Explosives have been used to break up the original plant without any apparent reason other than to prevent its remaining a memento . . . to money spent on foolish blundering which would not have been tolerated had it belonged to local proprietors.[48]

The company was in fact on the verge of bankruptcy. Financial difficulties, indeed, had appeared as early as October 1888 when £4,700 was urgently needed, and by December mortgages to debenture holders had had to be agreed to.[49] After this it was clear that little more cash would be forthcoming unless a dividend was paid. The alterations were expensive. Building water races, for example, was estimated to cost £6,500[50] and the water rights were a problem which was likely to involve continuing expense.[51] The building proceeded slowly; meanwhile the company was affected both by the drought and (paradoxically) by backwater on the tail race.[52]

In 1890, however, Russell's son Thomas achieved the coup that was in the end to save the company; he bought the Martha mine with its much richer seams, for the incredibly low price of £3,000. So short of funds was the company that he used his private money to do this, selling the mine to the company thereafter for £20,000 in shares: a dead loss of £3,000 should the company founder, as seemed only too likely. At the same time he acquired the Waitekauri mine, where he was free to make his own experiments on machinery. It would seem that the uncertainty over systems had led to conflict among the experts involved, a number of whom resigned at this time.

The management's desperation still did not drive them to buy the Cassel system: Gordon's latest calculations still suggested that the existing Waihi plant must be more profitable, when the royalty was taken into account.[53] The company, however, looked cautiously at other patents involving cyanide (and so open to challenge by Cassel) which might give a better return. The most interesting was Bohm's. Gordon had cautiously suggested that the specifications sounded, in some ways, preferable to the Cassel system. Bohm had, in fact, adapted a principle from the chlorination practice and planned to drive the cyanide solution up through the concentrate inside strong metal barrels and allow it to percolate back down. Waihi employed Bohm to erect and supervise the plant which, however, could not be made to work. The depth of the ore in the reversible cast iron cylinders was too much for the solution to penetrate so in practice it passed between the walls and the ore.[54] The company dismantled the apparatus and concentrated on altering and expanding its existing plant, which was a further heavy call on capital.[55] It was next argued that wet-crushing saved fuel, time and labour in the calcining kilns and should permit a higher throughput of ore at a cost of another £1,500 and a new building.[56] However, if anything like the same percentage of gold could be recovered, profits would increase, which would make the margin of advantage over cyaniding greater. A trial ten tons crushed at Waitekauri supported the idea. So, surprisingly, did James Napier, the newly appointed metallurgist who had been involved in the original Crown company experiments with cyanide.[57]

This was another failure. Wet-crushing actually increased the cost of working, reduced the bullion extracted by ten per cent and increased the wear and tear and the loss of mercury. In July 1892 the plant was reconverted.

The failure of this last experiment was pushing the company inexorably towards trying cyaniding. The experiences of two other local companies, however, must have caused them to hesitate. Te Aroha's copper-containing ores had not proved amenable to cyanide and the Sylvia mine had not been saved from closure by cyaniding. Despite the fact that cyaniding was being adopted elsewhere in the world, it was not providing a magic wand for New Zealand.[58] Nevertheless, on 21 December 1892, Dr. Schneidel, the expert who had set up the Sylvia works, was employed to advise the company on whether they should "go over to cyaniding",[59] and on 14 April an agreement was made with the Cassel company to use the process. The company, too, had compromised. The royalty was to be only 5 per cent.[60] At this point the Minutes fail us, but it was almost certainly inability to raise the necessary capital that led the company on 17 May to sell all its tailings to Cassel for £5,000, £2,000 in cash and the rest in promissory notes.[61] The cost of yet more untried plant had evidently daunted them: let Cassel carry the costs of construction. Perhaps, too, they hoped that Cassel would lose the patent action which was by then pending in the English courts.

McConnell took the 27,000 tons of tailings and ultimately recovered £30,000 in gold, that is, about one pound a ton.[62] The capital costs and the purchase price were comfortably recovered within a few months. If the directors of Waihi were mortified, at least they could now confidently adopt the process and so predict a future for the mine. By the end of October the first cyaniding tanks were being erected for the modest cost of £325. By January 1894 a much larger plant was under way.[63]

Even so, the company felt it necessary to send Schneidel to San Francisco for further information on cyanide. The plant built was for percolation, which was much cheaper than any form of agitation, but the system did not take out the coarse gold, and the best method of achieving this was not settled. The company may, furthermore, have sought information about the various processes now being proposed to improve the system and lower its costs. The loss of cyanide in decomposing pyrites was a cause for concern. Zinc precipitation was not entirely satisfactory, and an alternative, preferably one which would eliminate a further separation process, was sought. Various ideas circulated: an alkali wash with lime or caustic soda was possible for the first problem and electrolysis proposed for the second. An even weaker solution might then be possible.[64]

These were, however, embellishments. Essentially, the issue was solved and the mine embarked on an unprecedented period of expansion. The basic system established was percolation, after which the tailings were passed over a mercury table to catch the coarse gold. Later a variation on the chlorination method was introduced, whereby the solvent was first forced up and then permitted to percolate down.

The moment at which Waihi converted to cyanide was soon seen as the moment when the process was acknowledged as successful in New Zealand,[65] despite the fact that Karangahake had been using the process from 1889 and despite the earlier plants, some of which, like that at the Sylvia, had been effective.[66] Waihi's success was to open the way to others. In the following year the Try Fluke company at Kuatonu (at a cost of £64) and the Great Mercury both erected percolation plants, and a plant was being erected for the tailings of the Welcome at Boatness.[67] Russell was also introducing one at Waitekauri, although, characteristically and chronically experimental, he intended to leach to a depth of four foot, which was regarded as too great. These companies were not as spectacularly successful as Waihi and as others followed there were failures — either because cyanide could not separate the gold from the mineralisation such as copper, or because the ores were still too poor to be payable.

THE EFFECTS OF THE PATENT

Even when cyaniding was proven, the royalty still impeded its spread as it had initially impeded its adoption. Cases in the Court of Appeal in London rarely have men 12,00 miles away on the edge of their seats, but in April 1895 the attention of gold miners in New Zealand was certainly focussed there. In the previous November, Justice Romer had held that letters patent no. 14174 of 1887 were void.[68] If this judgement was upheld, the cyanide process would be freely available to all would-be users, while other processes, inhibited by the very general terms of the McArthur-Forrest patent, would be able to go ahead. The case was extemely complicated and held extraordinary legal interest.[69] It also brought together a large number of the best-known chemists of the day, such as Kelvin and Austen, and cast light on the state of the art in chemistry at the time. The basic problem related to the fact that the ability of cyanide to dissolve gold had been known for many years and a number of patents before the McArthur-Forrest patent had tried to make use of cyanide. Therefore, since the McArthur-Forrest patent did not specify any particular machinery or equipment but claimed a patent over the use of the solvent itself, could such a monopoly be sustained? The judgement, delivered by Lord Justice Smith, centred on the fact that there had been no prior commercial use of any previous patent. The patent was judged defective in its wording, but the patentees were allowed to amend their specification, in line with statute and prior patent practice, and the amended patent was regarded as valid.[70] In reaching their verdict, the judges were undoubtedly influenced by the weighty testimonial of the majority of academics, who virtually unanimously supported the novelty of the idea of using a dilute solution. In South Africa the judgement had gone the other way and there the Siemens-Halske process was used and claimed to be more economic. In the USA and elsewhere, however, the judgement mainly upheld the validity of the patent and the Cassel company continued to collect its royalties, which were heavy.

In New Zealand the disappointment was considerable. Practical gold-mining men felt that the London judges had, by some legal niceties, deprived them of the free use of a process which had been developed as a viable commercial system by mining men in New Zealand itself. Now it appeared to be priced beyond the means of companies who knew that with the existing alternative methods much gold was lost in the tailings. Many of them had already decided to ignore the judgement. There was little the company could do. The big companies who were worth taking to court, Waihi and three others, paid a lump sum for the rights, [71] but the small ones took advantage of the lawsuits pending to ignore the firm.[72] By 1897, at least six were doing this despite the fact that the company had won its case. At least another six or seven, more law-abiding, were looking to the New Zealand government to help them. The company itself also sought a compromise since an Appeal was still possible and the legal costs were mounting. After a detailed enquiry in which the company claimed £9,000 a year, it eventually sold the New Zealand rights to the government for a toal of £15,000.[73]

This opened the way for a widespread use of cyanide and experimentation with modifications to the system. Practices in cyaniding continued to vary. Some companies crushed dry and used percolating tanks, recovering the coarse gold later on mercury tables or blankets. Those who wet-crushed often did the reverse. The old mercury process of amalgamation was not dead, but it was increasingly subordinate, except in the Middle Island, where cyanide was not a success.

The patent law continued to complicate the manager's life. The vagueness of the Cassel patent raised continual problems over the legality of other patents which involved improvements to a basically cyanide system, such as the Siemens-Halske method. Experimentation, understandably, continued. Permanganate (with roasting) was used, as were chloride and bromide of cyanogen. The attitude of the mining men, however, was only one side of the coin: it is clear that the process would have attracted little attention but for the vigorous promotion undertaken by the Cassel company in the hope of profit.

EFFECTS ON THE STRUCTURE OF THE INDUSTRY

The cost of the new process was low measured in terms of the output of gold achieved, but it had a significant effect upon the structure of the industry. There was a noticeable growth in the size of firms. Low grade ores could now be worked, but cyaniding was profitable only in large scale continuous operations in which labour costs were kept down. It also required the services of skilled metallurgists, who were in short supply and could command good wages.

This, in turn, had its effects on employment. Pressure to keep wages down and profits up squeezed the miners and led to a deterioration in their lifestyle. This was not immediately apparent, but as the quality of the ore diminished, and alternative mining work in the area became scarce, wages became subject to a scissors effect. Since the cheap black labour which served its South African competitors was not available,[74] the Waihi company, mindful of the demands of its shareholders rather than of its workers, sought to exploit the institution of competitive contracting. Waihi is remembered in New Zealand history mainly for the six-month strike from 13 May to 12 November 1912, which amongst other things gave the country one of its first experiences of active unionism, demonstrations which broke into violence, the use of offensive weapons, police use of batons and *agents provocateurs.*[75]

The changing technology had certainly contributed to the altered nature of the industrial power structure. The success of the new technology had equally clearly served to attract capital to New Zealand and to assist the general economic expansion of the country at the turn of the century. Since its output was not significantly affected by either local or international cyclical fluctuations, gold production also gave the New Zealand economy a much needed stabilising effect before 1910, even though labour costs ultimately led to a sharp decline in the industry.[76]

CONCLUSIONS

Without the new technology, gold mining in the 1890s and 1900s would have continued to decline, with significant effects on the economy and politics of New Zealand. The way in which the new technology affected the structure, size and organisation of the industry in New Zealand was, however, itself shaped and modified by the nature of the existing society. South Africa, for example, had had much the same initial problems of comparatively low-grade pyritic or refractory ores. There, too, the organisation of production had been decisively changed by the cyaniding process and the industry rapidly came to be dominated by large scale capital intensive institutions drawing their resources from the British capital market. In both cases labour relations changed. In Africa, the demand resulted in the proletarianisation of black Africans, whose capacity to influence their conditions was far less than that of the white New Zealanders who came under pressure. In both cases, development was affected by government policy.[77] The actual attitude of government, however, seems in the long run to have been less important than the wider aspect of state control by which legal rights over property enabled or impeded the capacity to achieve monopoly. More basically, however, the New Zealand reefs were neither as plentiful nor as rich as the South African. By 1912 the Waihi company had squeezed almost the last drop of profit from its mines, and the strike, justified as it may have been, was merely the signal for a precipitous decline in gold mining.

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18. *ibid.,* 1886, Appendix C4a, pp. 2-3; 1886, Appendix C2, p. 4.
19. *ibid.,* 1886, Appendix C4a, p. 4.
20. *ibid.,* 1887, Appendix C5, p. 46.
21. *ibid.,* 1887, Appendix C5, p. 62. In this the ore was first crushed coarse with rolls, roasted and constantly stirred in a reverberatory furnace with three hearths, salt being added in the lower hearth. The ore was then sifted and either amalgamated in Wheeler pans with mercury, water and steam, or leached with hyposulphide of calcium or sodium, which dissolved the silver. After this the pulp was chlorinated and the gold precipitated.
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38. Plan, *ibid.,* 1891, Appendix C4, p. 32.
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44. Auckland Museum and Institute of Waihi records, Board minutes.
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46. Auckland Museum and Institute, *Minute Book* of Local Board of Directors, *passim.*
47. *New Zealand House of Representatives Journal,* 1894, Appendix C4, p. 4.
48. *ibid.,* 1890, Appendix C3, p. 41.
49. *Minute Book* of local board, p. 58.
50. *Minute Book* of local board, p. 72. In fact, the actual cost was higher, p. 115.
51. The warden demanded that in return for the number of sluice heads required the company make available to the public ten head of stamps between May and December.
52. *Australian Trading World,* 4 April, 1891.
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