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Technological Change and Mining Labour: Copper Mining and Milling Operations at the Britannia Mines, British Columbia, 1898 - 1937

by

Logan W. Hovis

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Department of History

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

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Abstract

Most recent studies of the relationship between technological change and mining labour in the western metal-mining regions of North America have concentrated on the impact of the mechanization of the industry that took place during the second half of the nineteenth century. The distinct impression is left that the increased use of machinery -- especially the machine drill -- was the chief factor in reducing the skill levels associated with mining as a craft tradition. Preoccupation with machinery has led to the assumption that by the beginning of the twentieth century the transformation to modern forms of mining was essentially complete and the traditional miner an anachronism.

Mining as practiced prior to 1900 differed qualitatively and quantitatively from the subsequent period of "modern mining;" but the introduction of machinery *per se* was less important to the reorganization of the patterns of work in the mines than the redesigning of the engineering systems in which workers and machines were employed -- a process which gained its full momentum in the decades after 1900. This transformation involved the gradual abandonment of low-volume, high-value, selective mining methods in favour of higher volume, non-selective methods which emphasised the quantity rather than the quality of the ore mined. The change redefined the nature of work in and around the mines, putting an end to a tradition of mining practice that was at least as old as the methods described in Agricola's *De Re Metalica,* something the initial mechanization of mining had never been intended to

accomplish.

Under selective mining practices, machinery was used to assist the skilled miner in his traditional task. Under non-selective or mass mining techniques, a new generation of engineers trained in the applied sciences redefined the miner's work as solutions were sought to the problems of an increasingly complex geology in a climate of rapid economic expansion, chronic over-production, generally declining metal prices, and ever increasing production costs. The efforts and successes of these engineers were amply demonstrated in the fields of mining, metallurgical, and human engineering. The impact of the change is evident in varying degrees throughout the metal-mining community; but by focusing on copper mining -- the technological leader from 1900 to 1930 -- the full impact of the industrial sciences on mine labour is evident.

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Contents

(cont.)

Introduction

The first three decades of the twentieth century were years of dramatic growth and change in the North American copper mining industry. Mine after mine opened to meet the demands of a rapidly expanding market; and increasingly larger proportions of the total production came from larger mines exploiting ores with lower copper contents than had previously been considered profitable. The years leading up to the end of the First World War were the most prosperous and optimistic the industry has ever known; by the 1920s the rapid expansion of the industry and changes in market conditions resulted in chronic overproduction and low metal prices. Taken as a whole, the first thirty years of the century were characterized by the rise of large production units and the adaptation of mass production techniques designed to lower operating expenses and emphasize the quantity rather than the quality of the ore mined.[1]

Mining, like a multitude of other industrial activities, moved towards a greater degree of mechanization in its activities and, more importantly, towards a more rational organization of production on an increased scale. In the process, the role of mine labour, and skilled labour in general, was transformed in what has been called the "Second" Industrial Revolution.[2]

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[1] Thomas R. Navin, *Copper Mining & Management* (Tuscon: University of Arizona Press, 1978): pp. 117 - 138.

[2] See David S. Landes, *The Unbound Prometheus: Technological Change and Industrial*

The skilled miner ceased to be a central figure in the success or failure of a mining operation as the ultimate responsibility for the production and processing of copper ore shifted to the new generation of technically trained mining and metallurgical engineers.

After 1889, copper was a central element in the growth of hard rock mining in British Columbia. Rossland's copper-gold mines made the metal respectable and the opening of the copper mines in the Boundary District demonstrated that large scale operations in low-grade ore bodies could be profitable. But the expansion of mining was not without its internal problems. In an otherwise laudatory assessment of the British Columbia mining industries, H. Mortimer Lamb, Secretary of the Canadian Mining Institute and the former editor of the *British Columbia Mining Record*, mentioned some of the changes to the structure of the industry and the problems that it still faced:

> ... the change that has taken place in British Columbia in the last year or so is a remarkable one, for it is a change of heart, of sentiment, and almost of character.... In short, the country is on a different footing altogether than before; it has come to see that it has a splendid stock in trade in great natural advantages, but that to turn these to full account business methods must be employed and followed. It is largely as a result of this that conditions have so entirely changed....
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> I am informed, meanwhile that at many of the mines, the labour item represents quite 80 per cent. of the cost charges -- surely an unduly high percentage. This high cost of labour falls, of course, more heavily on the smaller properties, not at the present profitably productive, than it does in the case of the larger mines, equipped with the very latest labour-saving machinery and handling large tonnages; but even these latter, which are chiefly to be found in the copper-mining sectors, cannot stand the strain now that the price of metal has undergone so considerable a decline.[3]

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[2](cont'd)*Development in Western Europe from 1750 to the Present* (Cambridge: Cambridge University Press, 1970), p. 307; and Craig Heron, "Hamilton Steelworkers and the Rise of Mass Production," in *Historical Papers* (Canadian Historical Association, 1982), p. 103.

[3] H. Mortimer Lamb, "Mining in British Columbia," *The British Columbia Mining Record* 14,11 (November 1907): 426 - 427.

Lamb's comments on labour costs, mechanization, and metal prices serve to underscore a number of basic problems associated with metal mining throughout the Western Cordillera of North America at the opening of the twentieth century.[4] Since the 1860s in the western United States and the late 1880s in western Canada the number, size, and economic importance of the hard rock mines had increased dramatically. Railway construction had provided a means of integrating remote mining districts into national and world economies; and increasing capital investment in mining, particularly in copper after 1880, produced fortunes for investors and ever increasing amounts of metal for world markets.[5] The mechanization of mining, particularly in so far as it related to the application of steam power and the machine drill, had begun to transform the overall technology of mining; but as Lamb noted, it had not significantly reduced the cost of labour in and around the mines. In effect, by the beginning of the twentieth century hard rock mining had become increasingly capital intensive while remaining labour intensive as well. Furthermore, metal prices were generally declining in response to the overall increase in world mineral production which grew at a greater rate than average consumption.[6] In confronting these problems, the metal mines of the Western Cordillera underwent a fundamental transformation based not so much on mechanization as a systematic reorganization of mining methods that culminated in a new technology and altered the relationship between labour and

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[4] The Western Cordillera is loosely defined as the mountainous portion of the continent bounded on the west by the Pacific Ocean and the Canadian Prairies and the Great Plains in the United States on the east. For the purposes of this study, the region extends south from Alaska and the Yukon to Mexico.

[5] Canada, Department of Mines, Mines Branch, *Report on the Mining and Metallurgical Industries of Canada, 1907 - 8* (Ottawa: Government Printing Bureau, 1908), pp. 81 - 89; United States, Department of Commerce and Labour, Bureau of the Census, *Special Reports, Mines and Quarries, 1902* (Washington, D. C.: USGPO, 1905), pp. 36 - 55.

[6] William L. Marr and Donald G. Paterson, *Canada, An Economic History* (Toronto: Gage, 1980), p. 360.

management that had been established during the initial expansion of the industry. The years after 1900 saw the rise of "modern mining" which was based on the application of mass production techniques, the increased use of cost control accounting with its emphasis on productivity, a new metallurgy, the increasing prominence of the technically trained engineer, and the general acceptance of science as a part of the industry.

The nature of the change and its impact on mining labour can be demonstrated through an overview of copper mining in the Western Cordillera and by a detailed study of the technical history of a given mine -- the Britannia Mining and Smelting Company's operations at Britannia Beach, British Columbia. The overview, drawn primarily from reports of the United States Bureau of Mines and other technical publications, demonstrates the increasing complexity of copper mining and the technical responses of the industry from the 1880s through the 1930s. The case study allows a closer look at the organization of work in a Canadian copper mine and demonstrates the shift of responsibility from the skilled miner to the technically trained practitioner of modern industry, the engineer, which is developed in the overview.

The Britannia mines were underground operations that were intially worked in 1898 and placed in regular production in 1905. Underground mining operations did not depart so quickly from prior practice as the open-pit mines which were the leaders in the low-cost mining of low grade ores; so, the example cannot be construed as an extreme case. Furthermore, the slower pace of change in underground operations allows a detailed observation of the transition from mechanized forms of tranditional mining to the process that came to be known as "modern mining." While change in underground practice was less rapid; the end result was much the same. The timing of the commencement of mining on the Britannia property is also convenient since it coincides with the early stages of the transition from traditional to mass methods of

mining. Finally, the Britannia mine is a useful example of mining and metallurgical engineering since it was not unionized until the 1940s which allows the description of engineering practice free from what the engineers, themselves, would have characterized as excessive restraints.[7]

In both the overview and the case study, the introduction of new types of machinery *per se* was less important in the mine's use of labour and in changes in the required levels of skill than were the engineering systems in which the machinery was employed. After 1900, the introduction of new mining systems -- which sometimes involved new machinery but were not necessarily defined in terms of those machines - redefined the nature of work in and around the mines; it also ended a tradition of mining practice that was at least as old as Agricola's *De Re Metalica*, something the initial mechanization of mining had never been intended to accomplish. Prior to 1900, machinery had been designed to assist the traditional miner in his traditional task: the location and careful removal of high-grade ores. Thereafter, the new generation of engineers restructured the tasks of mine labour as solutions were sought to the problems of mining increasingly complex ores with overall lower copper contents in an economic climate marked by generally declining prices and ever increasing production costs.

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[7] A mining community is a complex social organization that extends well beyond its technical elements; but, for the purposes of this study, elements of the community not directly related to the impact of engineering practice on the use of mine labour will only be discussed tangentially so as to not unduly complicate the discussion.

Technological Change and Hard Rock Mining

The rise of "modern mining" is closely associated with the corporate and managerial revolution that marked the late 1800s and early 1900s when the modern business enterprise centralized administrative control of the firm. Smaller endeavors were replaced as the model for business organization as it became apparent that "administrative coordination permitted greater productivity, lower costs, and higher profits than ... market mechanisms."[1] The increased size of the firm, centralized decision making to allow effective control of both costs and prices, the use of mass production methods, and control of the necessary technology were identified as the prerequisite of the modern corporation.[2] Using these criteria, Alfred Chandler has stated that American metal mining companies did not meet the terms of definition prior to the First World War. Only thereafter was copper mining, as the leading component of the industry, able to centralize control in a few major companies and begin to approach the definition of a modern firm.[3]

This assumption of slow growth and the late arrival of the modern firm in the mining industries has been challenged in so far as copper mining is concerned by

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[1] Alfred D. Chandler, Jr., *The Visible Hand, The Managerial Revolution in American Business* (Cambridge: Harvard University Press, 1977), pp. 6 - 9.

[2] *Ibid.*, pp. 240 - 241.

[3] *Ibid.*, p. 362.

Christopher Schmitz.[4] By discussing the copper industry in particular and not the mining industries in general, the increasing size of the copper companies is evident as early as 1909. In that year Anaconda Copper was ranked sixth among all industrial companies and had assets of $170.2 million. Anaconda was not unique in its size; in the United States alone nine copper companies were ranked in the top one hundred industrials with the smallest of these having assets of at least $25 million.[5] The reason suggested for this rapid growth was not the "price-fixing and market allocation objective in business combination" that was stressed by Chandler; rather it was "a function of a complex of geological and technical factors in the industry."[6] Chronic overproduction of copper precluded any sustained success in attempts by the various producers to control the volume or price of the metal on world markets.[7] The inability to control prices in an often volatile international market meant that growth was dependent on the nature of the ore bodies being mined and upon the successful application of changing techniques of mining to achieve lower costs and increased productivity from investments in new physical plants and in the use of labour.[8]

During the late nineteenth and early twentieth century the application of science to industry, that is modern technology, became increasingly identified with the professionally trained engineers and the engineers with their corporate employers. As

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[4] Christopher Schmitz, "The Rise of Big Business in the World Copper Industry 1870 - 1930," (Paper presented to the International Mining History Conference, St. Hilda's College, University of Melbourne, Melbourne, Australia, 29 August 1985.)

[5] *Ibid.*, "Table 1. Leading Corporations in the Copper Industry, 1909 - 1929," p. 3.

[6] *Ibid.*, p. 1.

[7] Schmitz drawns much of his evidence for the structure of copper prices and production from O. C. Herfindahl, *Copper Costs and Prices: 1870 - 1957* (Baltimore: Johns Hopkins University Press, 1959).

[8] Thomas R. Navin, *Copper Mining & Management* (Tuscon: University of Arizona Press, 1978), p. 117.

"industrial science" or "the science of systematic knowledge of the industrial art" technology is simply the ordering of men and tools to achieve a particular end.[9] Under a static technology, the available tools determine the pace and order of work. However, work consists of more than the simple use of tools. As Peter Drucker put it: "Work, its structure, organization, and concepts, must in turn powerfully affect tools and techniques and their development."[10] Technological change is at heart a result of problem solving and the implementation of one solution out of a range of possibilities. Those who perceive the problem and, more importantly, select the solution do so in their own best interests and reorder work -- persons and tools organized into systems -- by the same criteria.[11]

The identification of the engineer with his employer ensured that, "As engineers in a capitalist system, they were professionally charged with the profit-maximizing advance of scientific technology."[12] This association, when coupled with the assumption that labour is in effect one tool among many in a productive process, has far reaching implications in the relations between labour and management. As Herbert Marcuse has suggested:

> Technology as a mode of production, as the totality of instruments, devices, and contrivances which characterize the machine age, is thus at the same time a mode of organizing or perpetuating (or changing) social relationships, a manifestation of prevalent thought and behavior patterns, an instrument for control

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[9] Albert A. Fay, *A Glossary of the Mining and Mineral Industry*, U.S., Bureau of Mines Bulletin No. 95 (Washington: USGPO, 1920), p. 676.

[10] Peter F. Drucker, "Work and Tools," in *Technology and Culture, An Anthology*, eds. Melvin Kranzberg and William H. Davenport (New York: Meridian, 1972), p. 192.

[11] David F. Noble, *America by Design: Science, Technology and the Rise of Corporate Capitalism* (New York: Alfred A. Knopf, 1977), p. 251.

[12] *Ibid.*, p. 258.

and domination.[13]

Increasing sophistication in geology and metallurgy was an overall characteristic of the expansion of mining activity, but problem solving was initially approached on an *ad hoc* basis.[14] In the years after 1890, the new technology embodied in the professionally trained mining engineer began to appear in the North American West. While it was not immediately embraced by the jack-of-all-trades engineers who had participated in the opening the western mines, by the turn of the century the specialist was replacing the generalist and systems rather than tools were becoming the focus of technological change.[15] As the mining industries developed under the guidance of the new engineers, the ways in which labour was integrated into the new systems of work changed labour's role in terms of numbers, job classifications, skill levels, and particularly the degree of responsibility for the success of a given mining venture that was intimately associated with the skills of labour.

Two distinct discussions have developed around the impact of technological change on the use of labour in the hard rock mines of western North America. One is a product of the new social history which equates the industrialization of mining with its mechanization during a loosely defined period extending from 1860 to approximately 1910 or 1920.[16]

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[13] Herbert Marcuse, "Some Social Implications of Modern Technology," *Studies in Philosophy and Social Science* 9 (1941): 414.

[14] Rodman W. Paul, "Colorado as a Pioneer of Science in the Mining West," *Mississippi Valley Historical Review* 47 (1960): 34 - 50.

[15] Thomas Thorton Read, *The Development of Mineral Industry Education in the United States* (New York: American Institute of Mining and Metallurgical Engineers, 1941), p. 127 - 134, *passim*; Clark C. Spence, *Mining Engineers and the American West: The Lace-Boot Brigade, 1849 - 1933* (New Haven: Yale University Press, 1970), pp. 1 - 2.

[16] See Mark Wyman, *Hard Rock Epic: Western Mining and the Industrial Revolution,*

The second, and older, approach was developed during the 1930s and 1940s in the often self-congratulatory technical literature on mining and through the investigations of economists associated with the depression spawned agencies of the United States government. This approach subordinates mechanical devices *per se* to a larger framework in which mechanization is only one part of the rationalization of mining which was epitomized by the gradual adoption of mass production techniques in mining in response to geological and market conditions. The role of labour is a critical part of the discussion in that the abandonment of one set of engineering principles and the embracing of another transferred the ultimate responsibility for the success or failure of a mine from the skilled miner to the trained mining engineer and metallurgist.[17]

Curiously, the work of the new social historians has not drawn upon the earlier tradition for inspiration or information even though technological change and its impact on the labour force are central to both discussions.[18] More over, the chronologies overlap; Wyman and Brown end their discussions in 1910 and 1920 respectively which is in the midst of the period of change described in the engineering histories. Wyman based his end date on the assumption that by 1910 "the basic transformation was completed in technology, work organization, union formation,

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[16](cont'd)*1860 - 1910* (Berkeley: University of California Press, 1979); Ronald C. Brown, *Hard-Rock Miners: The Intermountain West, 1860 1920* (College Station: Texas A & M University Press, 1979); and Larry D. Lankton, "The Machine *under* the Garden: Rock Drills Arrive at the Lake Superior Copper Mines, 1868 1883," *Technology and Culture* 24,1 (January 1983): 1 - 37.

[17] For representative presentations of this position see A. B. Parsons, *The Porphyry Coppers* (New York: American Institute of Mining and Metallurgical Engineering, 1933); A. B. Parsons, ed., *Seventy-five Years of Progress in the Mineral Industry, 1871 - 1946* (New York: American Institute of Mining and Metallurgical Engineers, 1947); and especially Harold Barger and Sam H. Schurr, *The Mining Industries, 1899 - 1939: A Study of Output, Employment and Productivity* (New York: National Bureau of Economic Research, Inc., 1944).

[18] For example, neither Wyman nor Brown (cited above) make any mention of Parsons or Barger and Schurr in their texts or bibliographies; nor do they make wide use of the often very detailed discussions of labour and technology available through the Bulletins and Information Circulars published by the United States Bureau of Mines.

and protective legislation."[19] Brown selected 1920 because the mines "had become increasingly mechanized and the earlier generation's unique skills unnecessary [to the point that] the pride and sense of identity began to pass."[20] The engineering literature began its discussions in 1871 with the founding of the American Institute of Mining and Metallurgical Engineers and then let a sense of progress carry them forward from one technical problem successfully solved to another.[21] The economic discussions of mining technology were roughly co-terminus with the engineers and described change in machinery, techniques, and organization from 1870 until the 1930s. While the mining studies of the new social history are very machine conscious -- and in fact define industrialism in terms of mechanization[22] -- they have largely avoided or ignored a rich source of information on mechanization that is available in the technical literature, a literature that was intimately concerned with a very human enterprise: molding men *and* machines to meet the demands of an increasingly complex industry.

One solution to the gulf between the two approaches can be found in Otis E. Young's work on gold mining in the American West prior to 1893. Young's end date is significant because it coincides with the closing of the Turnerian frontier and, more importantly, because it "marked the obsolescence of the Heavy Industry Revolution, whose technical base had rested on steam power, reciprocating machine design, [and] the ingenious mechanic."[23] This suggestion established two distinct periods *vis-a-vis* the

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[19] Wyman, *op. cit.*, p. 6.

[20] Brown, *op. cit.*, p. *xiv.*

[21] Parsons, *Seventy-five Years, op. cit.*, p. *v.*

[22] "Industrialism is here defined as the adoption of machinery and power other than manpower or animal power to carry out a job, and the resulting social organization it creates." Wyman, *op. cit.*, n. 3, p. 261

[23] Otis E. Young, *Western Mining; An Informal Account of Precious-Metal Prospecting, Placering, Lode Mining, and Milling on the American Frontier from Spanish Times to 1893* (Norman: University of Oklahoma Press, 1970), p. *viii.*

role of labour while allowing for discussions of continuous changes in technique. The nature of the change was demonstrated in lode-gold mining, a moribund branch of the mining industry in the western United States during the late 1880s, with the introduction of first, improved concentration methods and then, the cyanide process.[24] First used commercially in New Zealand during 1889, cyanide was introduced into the United States two years later where, according to Otis Young, it set off a gold rush to the low grade veins and mine dumps passed over as unprofitable by earlier methods of gold extraction. While these events were overshaddowed by the excitement of the Yukon and Witswatersrand booms, it is unlikely that they would have attracted wide-spread, public attention as cyanide "was a very dull business, and it did little to stimulate moribund mining camps since it employed so few men. All it did was double the world's annual production of gold."[25] The development of flotation for base-metal recovery and the adaptation of mass mining techniques further changed other branches of the metal mining industries; but new technical processes alone should not be given full credit. As Young noted in his assessment of the cyanide process:

> Cyanide rang down the curtain upon the frontier period of American gold and silver mining, although cyanide was really more a symptom than a cause. Far more constructively important in closing out three thousand years of technolgy was the pressence in the twentieth-century mining camps of the young university-trained engineers .... There business was, in the words of one, "to do for sixpence what any fool could do for a shilling," and to the amazement of [an earlier generation of miners and mine managers] they did just that.[26]

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[24] Bureau of the Census, *1902, op. cit.*, pp. 576 - 577, 602.

[25] Young, *op. cit.*, p. 285.

[26] *Ibid.*, p. 286.

The transformation of labour history into working class history over the past twenty years has been based on the premise that "the proper study of labour history ought to be the worker, and not his institutions."[27] In both Canada and the United States the earlier emphasis on union organization and political action on the part of labour has been progressively challenged as the proper focus of attention and replaced by studies that attempt to set the individual worker in the context of a wider working-class experience grounded in the social and cultural dislocations that accompany economic development, particularly capitalist economic development.[28] One result of this change in emphasis has been that technological change and its impact on skilled workers, or craftsmen, has assumed an increasingly important role in labour history, particularly in so far as mechanization came to epitomize the industrial revolution and the subsequent development of an economy based on mass production. In the main, these studies of the impact of technological change in industry have followed the twin themes of "the degradation of work" and "the crisis of the craftsman;" both have been used to describe the reduction of skilled workers to the level of machine tenders or worse.[29]

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[27] David Brody, "The Old Labor History and the New: In Search of an American Working Class," *Labor History* 20,1 (Winter 1979): 111.

[28] For overviews of the emergence of the "new labour history" in North America, see Robert H. Zeigler, "Workers and Scholars: Recent Trends in American Labor Historiography," *Labor History* 13,2 (Spring 1972): 245 266; Herbert G. Gutman, "Work, Culture and Society in Industrializing America, 1815 - 1919," *American Historical Review* 78 (June 1973): 531 - 588; Brody, *op. cit.*, 111 - 126; Gregory S. Kealey, "Labour and Working-Class History in Canada: Prospects for the 1980s," *Labour/Le Travailleur* 7 (Spring 1981): 67 - 94; David J. Bercuson, "Through the Looking Glass of Culture: An Essay on the New Labour History and Working-Class Culture in Recent Canadian Historical Writing," *Labour/Le Travailleur* 7 (Spring 1981): 95 - 112; Kenneth McNaught, "E. P. Thompson vs Harold Logan: Writing About Labour and the Left in the 1970s," *Canadian Historical Review* 62,2 (June 1981):141 - 168; and Ian McKay, "Historians, Anthropology, and the Concept of Culture," *Labour/Le Travailluer* 8/9 (Autumn/Spring 1981/1982): 185 - 241.

[29] See Harry Braverman, *Labor and Monopoly Capitalism: The Degradation of Work in the Twentieth Century* (New York: Monthly Review Press, 1974); and Craig Heron, "The Crisis of the Craftsman: Hamilton's Metal Workers in the Early Twentieth

This shift has also been evident in the approach to the discussion of mining labour in the North American West. Since the early 1960s there has been a growing interest in hard rock, or underground, mining as an integral feature of the industrial penetration of the region. Metal-mining spread rapidly throughout this region during the second half of the nineteenth century and the first decades of the twentieth. In the United States the mid-nineteenth century gold rushes provided the initial impetus; and as the more accessible placer deposits were exhausted, the search for precious metals was continued underground. By the end of the 1870s the emphasis on gold and silver had been eclipsed by the production of base metals -- copper, lead, and zinc -- which were in constant demand by the manufacturing industries of the East, Great Britain, and Europe. In Canada, especially in British Columbia, a similar shift occurred by the end of the 1880s with the opening of the Kootenay and Boundary mining districts. In the process, the life of independence and self-discipline associated with the "romance of mining" was replaced by the discipline of wage-work and the employer.[30] As larger, better capitalized companies and corporations began to dominate mineral production, the result "was that many mining settlements were carried well beyond any stage of society that could reasonably be called the frontier. They became, instead, industrial islands in the midst of forest, desert, or mountain."[31] American historians began to acknowledge this change in the 1960s as they moved away from the romantic study of the gold rushes and devoted increased attention to the more socially and technologically complex era that followed.[32]

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[29](cont'd)Century," *Labour/Le Travailleur* 6 (Autumn 1980): 7 - 48. As Heron noted (pp. 11 - 12), "The literature on craftsmen has become voluminous."

[30] Wyman, *op. cit.*, 9 - 10.

[31] Rodman W. Paul, *Mining Frontiers of the Far West, 1848 - 1880* (New York: Rinehart & Wilson, 1963), p. 136.

[32] The American literature on western mining is considerably richer than its Canadian counterpart. See Rodman W. Paul's "Mining Frontiers as a Measure of Western Historical Writing," *Pacific Historical Review* 33 (1964): 25 - 34; and his "A

Systematic presentations of the changes in the structure of capitalist control of mining in so far as they relate to technology and the use of labour have led to generalized chronologies and oversimplifications designed, in part, to explain why North American workers have not created a sustained anti-capitalist labour or political movement.[33] In Canada, Wallace Clement has applied a distinction between the "formal" and "real" subordination of mining labour to suggest that the First Industrial Revolution in Canada transformed small, independent producers into wage labourers "without change in the technical conditions of employment." Real subordination came in the 1960s with "automation on the surface and mechanization underground."[34] The timing Clement suggests for the change from "formal" to"real" subordination implies that after the mines were organized for capitalist production at the turn of the century, little changed in the techniques of mining for fifty years. Therefore, underground miners were assumed to maintain a high degree of craft consciousness and control of their immediate workplace long after other industrial workers had been reduced to the level of interchangeable parts.[35]

More often than not, the complex technology of mining has been assumed while primary attention has been given to political events and union histories. Mining

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[32](cont'd)Tenderfoot Discovers There Once Was a Mining West," *Western Historical Quarterly* 10 (1979): 5 - 20. No comparable discussion exists for western Canada or, indeed, Canadian mining. The major study remains Harold A. Innis' "Settlement and the Mining Frontier," in *Canadian Frontiers of Settlement*, eds. W. A. Mackintosh and W. L. G. Joerg, vol. 9 (Toronto: Macmillan, 1936).

[33] See Bryan D. Palmer, *Working-Class Experience: The Rise and Reconstruction of Canadian Labour, 1800 - 1980* (Toronto: Butterworth, 1983); and David M. Gordon, Richard Edwards, and Michael Reich, *Segmented Work, Divided Workers: The Historical Transformation of Labor in the United States* (Cambridge: Cambridge University Press, 1982).

[34] Wallace Clemet, *Hardrock Mining: Industrial Relations and Technological Change at INCO* (McClelland and Stewart, 1981), pp. 20 - 21; see also his "The Subordination of Labour in Canadian Mining," *Labour/Le Travailleur 5 (Spring 1980): 133 - 148.*

[35] Clement, *Hardrock Mining, op. cit.*, pp. 94 - 162, *passim.*

labour studies have been primarily concerned with the emergence of a labour tradition that has been described as more militant and more radical than that which developed in the eastern industrial centres. Organizations such as the Western Federation of Miners and its off-shoot, the Industrial Workers of the World, operated freely on both sides of the Canadian-United States border. Along with the One Big Union, which also had an appeal in the mining districts, these organizations were usually described in terms that included direct action, industrial unionism, syndicalism, and socialism. In short, the western labour movements in both countries were seen as developing along exceptional lines quite distinct from their eastern counterparts, and the leading role played by miners' organizations was considered one key to the puzzle.[36]

In a 1966 article, Melvyn Dubofsky asserted that one cause of western radicalism was that "Technological innovations increased productivity, but in so doing diluted labor skills and disrupted traditional patterns of work [and reduced] some formerly skilled workers to unskilled laborers (and thus lowered their earning)."[37] The major piece of evidence to support this assumption was the 1892 Coeur d'Alene strike which was styled as a revolt against technological change, specifically the introduction of machine drills which displaced hand drillers and reduced many of them to lower paying positions as muckers and trammers.[38]

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[36] See Melvyn Dubofsky, "The Origins of Western Working Class Radicalism, 1890 - 1905," *Labor History* 7,2 (Spring, 1966): 135; John H. M. Laslett, *Labour and the Left: A Study of Socialist and Radical Influences in the American Labor Movement, 1881 - 1924* (New York: Basic Books, 1970), p. 241; David J. Bercuson, "Labour Radicalism and the Western Industrial Frontier, 1897 - 1919," *Canadian Historical Review* 58,2 (June 1977): 155; and H. Clare Pentland, "The Western Canadian Labour Movement, 1897-1919," *Canadian Journal of Political and Social Theory* 3,2 (Spring 1979): 53.

[37] Dubofsky, *op. cit*, 137 - 138.

[38] Dubofsky leaves the explanation of the technological nature of the strike to those who would pursue his footnotes. The discussion of the Coeur d'Alene Strike is taken from Vernon H. Jensen, *Heritage of Conflict: Labor Relations in the Nonferrous Metals Industry Up to 1930* (Ithica: Cornell University Press, 1950), pp. 28 29.

Eleven years later David Bercuson applied Dubofsky's technological condition to western Canadian mining and found it wanting. While he was willing to concede the dislocation inherent in rapid industrialization, he felt that as far as Canadian mining was concerned, "there was no technological revolution in mining because most coal and hard rock mining began *after* the major technological changes in the western United States had occurred." Put another way, Bercuson drew upon timing and the American domination of early hard rock mining in British Columbia to assume that the revolution in technique and tools had been completed before 1897 and then imported to Canada as current practice. Therefore, there could be no technological dislocation to foster miner militancy or labour radicalism.[39] This short-sighted and static view of technological change has been largely ignored in the literature. While the paucity of detail remains, technological change also continued to be considered a dynamic in labour relations. Recently, the collapse of the miners' union movement in Arizona which included the 1917 Bisbee deportation was credited, in part, to a "more advanced mining technology [that] created a greater need in the mines for unskilled labor and, at the same time, decreased the significance of the skilled 'miners.'"[40]

The obsession with union organization has been tempered in recent years with the publication of studies by Mark Wyman and Ronald C. Brown, both writing solidly

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[39] Bercuson, "Labour Radicalism," *op. cit.*, 157. The close association between the Canadian and American mining industries has long been assumed. See William J. Trimble, *The Mining Advance into the Inland Empire*, Bulletin of the University of Wisconsin No. 638 (Madison: University of Wisconsin, 1914); and E. S. Moore, *American Influence on Canadian Mining* (Toronto: University of Toronto Press, 1941).

[40] James W. Byrkit, *Forging the Copper Collar: Arizona's Labor-Management War of 1901 - 1921* (Tuscon: University of Arizona Press, 1982), pp. 30, 131. The failure of the Western Federation of Miners as an instrument of western labour organization and radicalism has provided the focus for much of the discussion of western mining technology. For a review of the main themes and commentators see John C. Foster's "Quantification and the Western Federation," *Historical Methods Newsletter* 10,4 (Fall 1977): 141 - 148; and "An Inquiry into the Fall of the WFM, and Summary of the WFM Codebook," in his *American Labor in the Southwest: The First Hundred Years* (Tuscon: University of Arizona Press, 1983), pp. 33 - 45.

within the confines of the "new" labour history. While they have taken pains to discuss the "miners' kaleidoscope existence" within the larger mining community, they have, unfortunately, retained a chronological identification with the earlier, "traditional" labour history. Both devote chapters to union organization which are the apparent justifications for extending their discussions into the twentieth century since miners' unions spawned in the 1880s and 1890s continued to be a component of labour-management relations in the western mines until 1921.[41] Their studies end arbitrarily in 1910 and 1920 respectively, dates that bear no specific significance in so far as the development of mining methods and the use of labour are concerned.[42] Otherwise, their works describe the transformation of hand mining and its associated "culture" into an industrial activity based on mechanization. In their over enthusiasm for the hand miner's skills and their collapse before the onslaught of mechanization, they ignore the technological events that truly destroyed the skills of the average miner: the adaptation of mass mining methods in the copper industry and the general transfer of authority from the skilled miner to the engineer.

Moreover, the identification of mechanization -- in particular the introduction of the machine drill -- with the period of major change in the use of labour is further emphasized by both writers. The increased size and depth of the mines made possible by steam engines and pumps, the use of new explosives, and the dust associated with machine drilling are credited with increasing the dangers associated with mining and lowering the overall quality of life afforded to miners in their working environment and their occupational structures.[43]

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[41] The collapse of the mining unionism is discussed in Jensen, *op. cit.*, pp. 452 - 466.

[42] Newell G. Bringhurst, "The 'New' Labor history and Hard Rock Miners in Nevada and the West," *Nevada Historical Society Quarterly* 24 (1981): 170 - 175.

[43] Wyman, *op. cit.*, 84 - 117. Chapter IV is entitled "Betrayed by the New

These features and a "mounting sense of desperation among workmen who felt that they were suddenly losing their capacity to protect themselves in a world dominated by trusts and corporations that could count on government allies" encouraged first unionism and then radicalism in the western mines.[44]

The entirely negative impact of the machine drill and the close association of its introduction with the origins of radical unionism put forward by Wyman and others has been seriously challenged by Larry D. Lankton's investigations of the Michigan copper mines. Underground mining in Michigan was well established long before the opening of the western mines. If a craft tradition based on hand tools is to be sought in nineteenth century metal mining, it is here that one should look. Yet, according to Lankton, "If the Michigan copper miners were betrayed by the Rand drill [fully introduced by 1880], then they bore their betrayal in silence." The introduction of machine drills had little immediate reflection in labour grievances or union organization. It was not until 1913-14 that machine drills were one strike issue among many in the Michigan mines, and then the issue was that newer, lighter weight drills reduced the size of the drill crews from two men to one which altered traditional work patterns and raised concerns for the safety of the drillers.[45]

Wyman's assertion that the more complex technology increased the dangers of mining has also been challenged by Ronald C. Brown in his *Hard-Rock Miners: The Intermountain West, 1860 - 1920.* Using evidence gleaned from technical reports published by the U. S. Bureau of Mines, Brown suggests that the rate of accident

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[43](cont'd)Technology," a phrase which aptly describes Wyman's assessment of the relationship between miners and mechanization.

[44] *Ibid.*, 227.

[45] Lankton, *op. cit.*, 30. For detail on the introduction of the one-man drill, the 1913-1914 strike, and the increasing pace of technological change in the Michigan copper range, see William B. Gates, Jr., *Michigan Copper and Boston Dollars* (1951; reprint ed., New York: Russell & Russell, 1969), pp. 125 - 135.

and fatality was higher in the mines which were less mechanized and that problems associated with the new techniques were associated with "both the ignorance of the miners and the inadequate procedures for evaluating the performance of the new machines, methods, and materials."[46] The problem with this argument is the evidence relevant to the period 1910 - 1920 is used to make a blanket statement for the larger period 1860 - 1920. Furthermore, Brown appears to be only partly aware of larger changes occurring in the methods and management of mining in the latter half of his period:

> Techniques of mining and the instruments of extraction changed so drastically in the years between 1860 and 1920 that the industry was transformed. Yet, in another sense, the basic procedures changed very little; machines had aided or displaced men rather than transformed the process itself. Mining underwent continuous industrialization. Dynamite, air drills, electricity, hoisting cages, underground railroads, drainage tunnels, square-set timbering, block caving techniques, and finally open pit (steam-shovel) mining had made possible mining at greater depths, mining of lower-grade ore, mining of heretofore unreachable ore bodies.[47]

Brown's overall assumption is a contradiction, not a paradox. By 1920 the basic procedures of mining had undergone fundamental change in at least one branch of the industry: copper mining. Furthermore, the inclusion of block caving techniques and open pit mining -- several of the symptoms if not the agents of the change -- in the same category as dynamite and air drills is to miss the distinction between tools and systems.

The question of unionism in the western metal-mines was first given articulate shape by Vernon Jensen in 1950. Yet, while most subsequent writers on the subject

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[46] Brown, *op. cit.*, pp. 81 - 82.
[47] *Ibid.*, p. 81.

have paid homage or criticised his work, they have, in the main, either avoided or ignored one of his conclusions as to the final collapse of the miners' unions in the years after the First World War.

> The key to unionism in the industry came more and more to be copper. If Butte, southern Arizona, and Bingham had been unionized, other parts of the industry could have been relatively easily organized or held under unionism. Without them, there was slight chance to organize or hold the others. Important in this respect is that copper mining and smelting were on a mass production basis and companies were operating, except for Butte, so that the traditional hard-rock miner kept gradually fading out of the picture. His place was filled more and more by unskilled workmen. In the decade of the twenties, the industry came more and more to fit into the category of what was then the almost universally unorganized mass production field. Sheer size, to say nothing of latent if not overt opposition, made it difficult to organize the men.[48]

While the works of Wyman and Brown have provided detailed and useful studies of life in the mines during the second half of the nineteenth century their efforts to extend the discussion into the twentieth century have resulted in the mistaken impression that the major changes in mining technology occurred before 1900. In fact, the truly revolutionary changes in western mining were only just beginning and "the basic procedures" of the industry -- its management and its methods -- would be greatly altered.[49] In part, the problem stems from an attempt to view the western mining industries as a whole. While no one confuses coal mining technology with hard rock mining, few recent students have bothered to distinguish between the various

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[48] Jensen, *op. cit.*, pp. 463 - 464.

[49] Wyman and Brown are not alone; most Canadian writers on working class history ignore the "Second" Industrial Revolution in favour of detailed studies of the "First." Craig Heron, "Hamilton Steelworkers and the Rise of Mass Production," in *Historical Papers* (Canadian Historical Association, 1982), p. 103. The American literature on the subject is somewhat more developed. See, for example, David Montgomery, "The 'New Unonism' and the Transformation of Workers' Consciousness in America, 1909 - 1922," *Journal of Social History* 7 (1974): 509 - 529.

branches of metal mining. The apparent assumption is that the techniques of work and the use of labour in gold mines, silver mines, lead mines, and copper mines are much the same and can be covered in one general discussion. This assumption ignores geology, market structures, and differing methods of recovery in the distinct branches. If the proper study of labour history is the worker, it should be essential that some understanding be gained of the work he does; and if the proper study need not be concerned with workers' institutions, it does not follow that there need be no concern with the technical structures and corporate institutions that encompass and employ him.

The depression of the 1930s generated an intense interest in the prospects for technological salvation in engineering and government circles and at the same time encouraged investigations into the history of technology in so far as its antecedents might indicate future trends.[50] The investigation extended to the mining industries which were hard hit by the depression. Detailed studies of technological change in the various branches of the industry were issued as reports of the National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques, a joint effort by the United States Bureau of Mines and the Federal Works Agency, Work Projects Administration, between 1936 and 1940. The distinction between tools and systems and the peculiar qualities of the several branches of the industry were not overlooked in these studies; and the differing rates and nature of change was closely noted.[51]

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[50] United States, Congress, House, National Resources Committee, Subcommittee on Technology, *Technological Trends and National Policy, Including the Social Implications of New Inventions*, House Document No. 360, 75th Cong., 1st sess., June 1937 (Washington, D. C.: USGPO, 1937), pp. 3 - 14.

[51] For example, see L. N. Plein, F. E. Berquist, AND F. G. Tryon, *Mechanization Trends in Metal and Nonmetal Mining as Indicated by Sales of Underground Loading Equipment*, Mineral Technology and Output per Man Studies Report No. E-3 (Piladelphia, Pennsylvania:National Research Project, June 1937).

The changing role of labour in terms of numbers and skill levels resulting from the introduction of new tools and systems of organization formed an important part of these studies. Furthermore, a consistent effort was made to ensure that these changes were viewed in the widest possible context. In the case of introduction of the rock drill it was noted that the period of initial introduction (1880 - 1909) was also a time of generally expanding mine production and that overall employment actually increased. It was only after 1919 that changes in drilling techniques contributed to declining employment figures, and then, the reduced numbers resulted from a reorganization of the use of drilling designed to produce larger volumes of ore per foot drilled, not from any intrinsic benefit contained in the drills themselves. Declining employment in drilling was, in the main, offset by increased manpower requirements in the transportation and processing of the larger volumes produced.[52] In so far as the skill levels required for the task were concerned, the driller's abilities and need for physical strength were not directly challenged by the initial replacement of hand techniques by machine drilling. A knowledge of hole placement and explosives, as well as physical stamina, were necessary with both methods. The drills were heavy and the setup procedures required not only strength but often a high degree of dexterity. And new skills were required: the efficient use of the machines required a good ear and feel for changes in the nature of the rock being drilled. In addition, the driller and his helper had to be something of a mechanic to keep the machines running. Finally, as the design of the drills was improved in the first three decades of the twentieth century, the "modern drill runner [became] a specialist skilled in getting the maximum footage. He must be alert and have quick reaction time and sufficient intelligence to understand and obey orders. He need not have the physical strength and endurance of

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[52] C. E. Nighman and O. E. Kiessling, *Rock Drilling*, Mineral Technology and Output per Man Studies Report No. E-11 (Philadelphia, Pennsylvania: National Research Project, February 1940), pp. 140 - 144.

his hand-drilling prototype...."[53]

Overall, skill levels were diluted, not so much as a result of reduced requirements for the running of specific machines as a consequence of the increased need for larger numbers of non-skilled or semi-skilled labourers to move the larger volumes of ore. As Wyman noted, the definition of a miner changed as the size of operations increased. As the work of the mines was subdivided into specific tasks -- timberman, carpenter, blacksmith, powderman, hoistman, mucker, and trammer, for example -- union organizations expanded their definition to include all workers employed underground, on the surface, in the concentration plants, and even in the smelters when they were closely associated with the mines.[54] At the same time, the definition of a miner as a skilled trade was defined in progressively narrower terms: first it was restricted to anyone working underground and, later, the term "miner" was used only for "one who drills, blasts, stopes, drives levels, etc., in a mine."[55] By this limited definition, the miner had continued to be a highly skilled craftsman with the advent of mechanization; he had simply been given better tools with which to perform a traditional task.[56] But, it was no longer this skilled miner who comprised the bulk of the employees in and around a mine. Using the wider definition of a miner, the *Engineering and Mining Journal* acknowledged wide sweeping changes in the nature of the workforce. "The itinerant, self-reliant miner, jack of all trades, and master of several" was a disappearing breed, and:

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[53] *Ibid.*, 144 - 148.

[54] Wyman, *op. cit.*, pp. 160 - 161.

[55] Fay, *op. cit.*, p. 436.

[56] Barger and Schurr, *op. cit.*, pp. 105 - 106.

> The new type of miner is not so intelligent, but he is more obedient and more industrious. He works generally for less than the scale established at such camps as Butte and Goldfield. By himself he is far less efficient, but as part of a system employing a multitude of bosses, he probably delivers a lower labor cost per ton. To many companies he is a more desirable employee than a skilled miner, even when the latter will work for the same wages.[57]

The changes in the nature of the miner resulted from changes in the techniques of mining. As mining was reorganized along lines similar to factory production, the skilled miners became increasingly redundant and the unskilled or semi-skilled worker became the essential core of the mine labour force.

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[57] *Engineering and Mining Journal*, 95,10 (8 March 1913): 534.

The Origins of "Modern Mining" in the Western Cordillera

In his preface to the 1927 edition of the *Mining Engineers' Handbook*, Robert Peele explained why a "radical revision" of the book was necessary only nine years after it was first issued: "Since the publication, in May, 1918, of the first edition of this book -- most of the material for which was collected from 1915 to 1917 -- important changes have taken place in the mining industry. Most of these changes are due to the development of engineering practice; others are economic results of the Great War." Not only had new approaches to mining and mineral processing been made available, "high wages [had] stimulated everywhere the introduction of economies, and the wider use than ever before of labor saving methods and machines."[1] Peele's emphasis on the rapidity of change, rising costs, labour saving methods, and especially engineering practice served in 1927 to acknowledge a transformation in hard-rock mining and establish a firm demarcation between the traditional mining methods of the nineteenth century and the era of "modern mining" that was to follow. The second edition also demonstrated the increasing specialization within the field of mining engineering. In the preface to the first edition, Peele declared that "In practice, no well-defined boundary exists between the fields of work of the mining engineer and the metallurgist."[2]

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[1] Robert Peele, ed., *Mining Engineers' Handbook*, 2d rev. ed., 2 vols. (New York: John Wiley & Sons, 1927), 1: iii - v.

A scant nine years later his introductory remarks stated that discussion of metallurgy, or ore dressing, were not "strictly in place in a book on mining."[3] If Peele had also discussed the increased use of incentive plans designed to increase worker productivity he would have touched on all three hallmarks of "modern mining:" mining, metalurgical, and human engineering.

In the hard-rock mining districts of the Western Cordillera, the passing of the nineteenth century was marked by a vastly increased reliance on the geological, chemical, and physical sciences in the location, design, and operation of a mine.[4] Lode-mining ceased to be the almost haphazard search for easily extracted, high-grade ores and became increasingly the systematic exploitation of low-grade deposits that had been passed over as unprofitable in the initial phases of western exploration. The mining of such deposits demanded a close attention to costs if the venture was to be profitable and encouraged an almost continual quest on the part of mining management for ever greater levels of efficiency in both the methods of production and the use of labour.[5] After 1900, the metal-mining industries became increasingly mechanized and organized for mass production which changed the basic structure of mining as an industry and an occupation and altered the relationship between employer and employee that had developed during the last half of the nineteenth century.

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[2](cont'd)[2] Robert Peele, ed., *Mining Engineers' Handbook*, 1st ed. (New York: John Wiley & Sons, 1918), p.*iii*.

[3] Peele, 2d rev. ed., *op. cit.*, 1: iv.

[4] A. B. Parsons, *The Porphyry Coppers* (New York: American Institute of Mining and Metallurgical Engineers, 1933), p. 1.

[5] The technical literature of the period amply demonstrates this concern. For two early examples see John E. Hardman, "A Method of Cost Accounting, with Special Reference to Mines," *The Journal of the Canadian Mining Institute* 3 (1900): 37 - 67; and Glenville A. Collins, "Efficiency Engineering Applied to Mining," *Transactions of the American Institute of Mining Engineers* 43 (1913): 649 - 662. For a present day assessment of the importance of these principles see Thomas R. Navin, *Copper Mining & Management* (Tuscon: University of Arizona Press, 1978), p. 117 - 118.

Before 1900, "to be a miner ... required good judgement as well as industry. A miner at that time was an artisan whose skill was founded upon an apprenticeship and long practice."[6] As the size of operations increased and as the division of labour was increasingly applied to mining, the skilled miner, the "jack-of-all-trades," and the large numbers of unskilled labourers that had supported him were replaced by men trained for specific tasks and working "under the immediate supervision of experienced foremen in accordance with plans prepared by technically trained mine superintendents and mining engineers."[7] By 1930, the average wage earner in and around the mines had been transformed from a skilled craftsman or an unskilled labourer, both with a clearly defined and well understood function, into a semi-skilled machine tender concerned more with the quantity than the quality of production.[8]

While change was evident in every aspect of mining, including precious metals, coal, iron, oil and gas, "The transition to modern methods of mining first appeared in the extraction of copper ores."[9] The demand for copper grew at a greater rate than that for other industrial metals. Brass was an essential element in steam power technology; and after 1880, the requirements of the electrical industry outgrew the capacity of the traditional producers in Europe and Northern Michigan.[10]

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[6] C. E. Julihn, "Copper: An Example of Advancing Technology and the Utilization of Low-Grade Ores," in *Mineral Economics*, eds. F. G. Tryon and E. C. Eckel (NewYork: McGraw-Hill, 1932), p. 128. While this is a romanticised view of the western miner, there is more than a grain of truth in it.

[7] Y. S. Leong, Emil Erdreich, J. C. Burritt, O. E. Kiessling, C. E. Nighman and George C. Heiker, *Technology, Employment, and Output Per Man In Copper Mining*, National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques, Report No. E - 12 (Philadelphia: Work Projects Administration, February, 1940), p. 181.

[8] Harold Barger and Sam H. Schurr, *The Mining Industries, 1899 - 1939: A Study of Output, Employment and Productivity* (New York: National Bureau of Economic Research, Inc., 1944), pp. 105, 115 - 116.

[9] *Ibid.*, p. 107.

By 1900, North America, particularly the United States, dominated world copper markets as the western mines began to make significant contributions to world production. When Canada and Mexico are included, North America accounted for 65 percent of world production between 1900 and 1925.[11] The increases in production were accompanied by geographic shifts in mining centres and by changes in mining and processing technology. The dominance of the Lake District of northern Michigan prior to 1880 was based on the presence of ores bearing primarily native copper which required minimal processing - basically the separation of the native copper from the waste rock - to produce a final product.[12] As Montana, Utah, and Arizona were integrated into the national economy more copper was derived from complex sulphide ores which required extensive treatment and concentration before being shipped to smelters and refineries for final treatment. Complex ores in the West and declining grades of ore in both areas placed strains on the conventional methods of mining and processing which were only over come by extensive changes in the technical conduct of the industry and an increased reliance of scientific knowledge and the engineer as its practioner.[13]

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[10](cont'd)[10] Navin, *op. cit.*, pp. 11 - 13. There was a general increase in the demand for all base metals to meet the needs of an increasingly complex metallurgy, but copper production far oustripped lead and zinc production. See Elmer W. Pehrson, "Seventy-five Years of Progress in Mineral Production -- the Statistical Record," in *Seventy-five Years of Progress in the Mineral Industry, 1871 - 1946*, ed. A. B. Parsons (New York: American Institute of Mining and Metallurgical Engineers, 1947), pp. 365 - 367. See also Christopher J. Schmitz, *World Non-Ferrous Metal Production and Prices, 1700 - 1976* (London: Frank Case, 1979).

[11] World production for 1900 - 1925 was 25,726,406 short tons of copper. North America accounted for 16,920,711 tons with the United States producing 14,542,269 tons or 56.5% of the world total. Mexico produced 5% and Canada added another 3.5%. See E. D. Gardner, C. H. Johnson and B. S. Butler, *Copper Mining In North America*, U.S., Bureau of Mines, Bulletin No. 405 (Washington: United States Government Printing Office, 1938), Table 1, p. 2.

[12] William B. Gates, Jr., *Michigan Copper and Boston Dollars: An Economic History of the Michigan Copper Mining Industry* (1951; reprint ed., New York: Russell & Russell, 1969), pp. 22 - 27.

[13] "These activities include[d] the development of new and improved techniques,

The production of copper from complex ores requires a number of distinct but interrelated operations. First, the actual mining of the ore involves the separation of the mineral bearing rock from the ground and its transportation to the surface or some other convenient collection point. Then, since these ores are not usually amenable to immediate smelting, they are milled and concentrated[14] to increase the percentage of copper contained to a point where it can be economically shipped to a smelter. The concentrate which rarely contains more than 25 percent copper is there converted into copper matte, a crude metal. Finally, a usable product is produced at the refinery and delivered to fabricators and other customers.[15] Since the smelting and refining operations are often conducted at great distance from the source of the ore, the operations at the mine can be considered to consist of the actual mining, the transportation of the ore and associated waste rock on the property, the concentrating of the mine's production, and the support services necessary to keep the entire operation functional. The distinction between mining/concentrating and smelting/refining is reinforced by the rapid reduction in numbers after 1900 of smelting operations that were closely associated with individual mines and the increasing importance of custom smelters.[16] Consequently, discussions of mine labour, in the broadest sense, includes all

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[13](cont'd)methods, processes and mechanics for (1) finding new deposits, (2) removing the crude minerals from the ground, (3) beneficiating the crude materials and converting them to refined form, (4) processing of many kinds, and (5) utilization by industry," in short, the discovery of engineering solutions to engineering problems associated with mining. Louis Shattuck Cates, "Introduction", in *Seventy-Five Years in the Progress in the Mineral Industry, 1871 - 1946*, ed. A B Parsons (New York: AIMME, 1947), pp.vii - viii

[14] Milling properly refers to the crushing of the mine rock in preparation for separating waste rock, or gangue, from the ore bearing rock by various concentration methods. In practice, the terms mill and concentrator are used interchangeably to describe both the processes and the building in which they are conducted. Albert F. Fay, *A Glossary of the Mining and Mineral Industry*, U. S., Bureau of Mines Bulletin No. 95 (Washington, D. C.: USGPO, 1920), pp. 176, 435.

[15] Navin, op. cit. pp. 25 - 69.

[16] Ibid., pp. 55 - 56. See also James E. Fell, Jr. *Ore to Metals: The Rocky Mountain Smelting Industry* (Lincoln: University of Nebraska Press, 1979), *passim.*

those employed at the mine site in the actual mining, milling, and supporting operations but not smelting or refining.

Prior to 1850, metal mining in North America was a relatively simple process requiring a limited number of hand tools, good luck, and, above all, common sense. Most mines were little more than surface excavations of high-grade ores operated by small groups or individuals.[17] Perhaps the most sophisticated underground operations of the period were the copper mines of Upper Michigan which opened after 1844. At first, mining in the region consisted of little more than blasting native copper free from surface outcrops. Shallow shafts and short drifts were driven using hand drills, sledges, and black powder. The broken ore was sorted in open stopes from the waste rock by hand, moved to the shafts by hand, and finally, raised to the surface by hand or horse power. Once on the surface, the ore was broken by hand sledging to further separate the native copper from the rock matrix. Such systematic milling as was done in this early period involved crushing the rock in stream powered stamp mills and the use of water and gravity to separate the copper from the waste in a manner similar to that used in California to recover placer gold.[18] As the costs of this type of operation were high, the concentration of copper in the ore had to be high if a profit was to be made; "selective mining [i.e. taking only the best ores] came into extensive use, not so much as from choice as from necessity."[19]

The Michigan copper mines became more sophisticated in their mining methods during the same period (1860 - 1900) that saw the birth and initial growth of hard rock mining in the Western Cordillera. Lode mining was qualitatively different from

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[17] Barger and Schurr, *op. cit.*, pp. 97 - 99.

[18] Gates, *ep. cit.* pp. 4 - 5.

[19] W. R. Crane, *Mining Methods and Practice in the Michigan Copper Mines*, U.S. Bureau of Mines, Bulletin No. 306 (Washington: US GPO, 1929), p. 5.

the placer workings that had fueled the gold rushes. While placer mining could be accomplished by small groups using rude tools and limited capital, deep mining required more sophisticated techniques, greater amounts of capital, and a much larger labour force of both skilled and unskilled workmen to operate the mines and their associated concentrators and smelters.[20] Almost from the begining of underground mining the complexity of the operations made it difficult to define a miner in any traditional sense of the word. The work involved much more than digging for metallic ores. A large and varied force of labourers, including "timbermen, carpenters, blacksmiths, pick handlers, water boys, powdermen, engineers, hoistmen, cagemen, and various types of shift bosses, formen, and other supervisors," were involved in the operation of a mine.[21] While there were significant numbers of Cornishmen and others with prior training as miners from the beginning, many others with no prior industrial experience of any kind were included in the heterogeneous population that fulfilled the labour requirements of the new mines. Furthermore, a large number and range of skills and services were required to keep the mines working.[22]

The rapid spread of hard rock mining in the North American West after 1860 was initially based on the exploitation of metallurically simple, high-grade ores which presented few problems for the recovery techniques of the nineteeth century. Only the best grades of ore were taken to the surface -- those with the highest concentration

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[20] Richard E. Lingenfelter, *The Hard Rock Miners: A History of the Mining Labor Movement in the American West, 1863 - 1893* (Berkeley: University of California Press, 1974), p. 3.

[21] Mark Wyman, *Hard Rock Epic: Western Miners and the Industrial Revolution, 1860 - 1910* (Berkeley: University of California Press, 1979), pp. 160-161

[22] In 1880, the mines on Nevada's Comstock Lode employed 2,840 men. Of these, 1,974 were classed as miners. The remaining 866 were divided among more than thirty distinct job classifications including 95 blacksmiths, 162 engineers, 124 labourers, 54 machinists, and a wide variety of other trades. United States, Department of the Interior, Census Office, *Statistics and Technology of the Precious Metals* (Washington, D. C.: USGPO, 1885), p. 158.

of the desired metal and the simplest possible chemical composition. In part, this was due to limited transportation links to the wider world the in years before 1880 which encouraged an emphasis on gold and silver. It also reflected a recognition that fully one-half of the metal content of the ore raised to the surface would be lost in the concentrating, smelting, and refining processes.[23] Mining in this manner was often a wasteful and short-lived venture that was only sustained by exceptionally large or rich ore bodies or by the continuous discovery of new mining districts as the older ones were mined out. It is possible to partially explain the rapid mineral exploration of the North American West and the geographical expansion of mining industry with this need for high-grade ores.[24] As a result, most of the potential mining districts from California to the Black Hills and from Arizona and New Mexico to British Columbia had been identified well before 1900.[25]

Throughout the nineteenth century underground mining practice was closely associated and interdependent with the capacity and efficiency of the surface processing plant. The capacity of the plant set practical limits on the mine production that could be processed without stockpiling ore, and the efficiency determined the minimum grade of ore that could be profitably extracted. Until 1912, milling (or concentrating) practices were dominated by gravity methods: gravity stamps were used to crush the ore and differences in specific gravity were used to separate the ore from the waste in a complex array of mechanical separators.[26]

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[23] Julihn, *op. cit.*, p. 127.

[24] Chas. F. Jackson and J. H. Hedges, *Metal-Mining Practice*, U. S., Bureau of Mines Bulletin No. 419 (Washington, D. C.: USGPO, 1939), pp. 385 - 386.

[25] Vernon H. Jenson, *Heritage of Conflict: Labor Relations in the Nonferrous Metal Industry Up to 1930* (Ithica: Cornell University Press, 1950), p. 4.

[26] Arthur F. Taggart, "Seventy-five Years of Progress in Ore Dressing," in *Seventy-five Years of Progress in the Mineral Industry, 1871 - 1946*, ed. A. B. Parsons (New York: American Institute of Mining and Metallurgical Engineers, 1947),

While improvements to these systems had increased their efficiency somewhat, that rate of recovery was still low, ranging from 60 to 75 percent, which did little to substantially increase the ability to process ores with an average grade below two percent.[27]

The initial introduction of machinery into a mine increased the productive capacity of the underground labour in some aspects of the mining process but not others. After 1870, machine drills, high explosives, powered hoists, and pumps greatly facilitated access to the ore at greater depth with greater speed. But, the need to selectively mine -- that is, take only those ores which were compatible with the capacity and capabilities of the the surface plant -- served to retard the wholesale mechanization of underground mining.[28] While mechanized methods eased the access to the ore, the high costs of transportation and the inefficiency of recovery dictated that the actual winning of the ore would remain a hand process for some time with hand drills and light charges of low explosives such as black powder used to break the ore itself. In some mines blasting in the ore was entirely forbidden; instead picks and bars were used to break down the ore in a way that minimized spreading it over a wide area and thus diluting it with waste rock.[29] Additional restraints were placed on the wide-scale adaptation of machine drills and other devices by the need to balance the restrictions placed on the size of stopes and other working areas necessary to produce the required grade of ore with the minimum space requirements necessary to set up and operate the machines.[30]

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[26](cont'd)pp. 98 101.

[27] T. G. Chapman, *Trends in Practice and Costs of Concentrating Copper Ores*, U. S., Bureau of Mines Information Circular No. 6792, September 1934, p. 1.

[28] Chas. F. Jackson and E. D. Gardner, *Stoping Methods and Costs*, U. S., Bureau of Mines Bulletin No. 390 (Washington, D. C.: USGPO, 1936), pp. 30 - 33, 42 43.

[29] Julihn, *op. cit.*, p. 127.

The transition from hand to machine drilling was a slow process that took from 1880 to 1909; and mines with high grades of ore, such as the Anaconda mines at Butte, were more likely to introduce mechanical drilling in the ore than those with lower overall grades.[31]

While there were numerous health and safety problems associated with the introduction of machinery underground, the essential role of the miner remained unchanged. Under selective mining methods "the miner had developed into a highly skilled craftsman with a clearly defined function ... charged with the responsibility of extracting as much of the mineral with as little waste as possible."[32] As late as 1900, the mechanization of underground mining was primarily associated with auxillary functions such as pumping and hoisting. Compressed air drills were primarily used for tunneling and shaft sinking to gain access to the ore, while hand drills and even picks were used to remove it. The rationale behind this distinction in drilling practice was the assumption that hand methods produced lower volumes but higher grades of ore.[33] Dependence on the skill of the underground miner was further enhanced by the advancing method of mining which was common before 1900. Once a prospect had been located and sufficient capital raised, the miners would proceed inward and down on faith from the initial outcrop in a process which placed a premium on the miner's ability to find and follow the ore body.[34]

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[30](cont'd)[30] James F. McClelland, "Prospecting, Development, and Exploitation of Mineral Deposits," in *Mining Engineers' Handbook*, ed, Robert Peele, 1st ed. (New York: John Wiley & Sons, 1918), pp. 487 - 488.

[31] C. E. Nighman and O. E. Kiessling, *Rock Drilling*, Mineral Technology and Output per Man Studies Report No. E-11 (Philadelphia, Pennsylvania: National Research Project, February 1940), pp. 138 - 142.

[32] Barger and Schurr, *op. cit.*, pp. 105 - 106.

[33] *Ibid.*, p. 106.

[34] L. C. Groton, "Seventy-five Years of Progress in Mining Geology," in *Seventy-five Years of Progress in the Mineral Industry, 1871 - 1946*, ed. A. B. Parsons (New

Modern mining transferred the responsibility for the success of a mining venture to technically trained personnel. While no single event adequately characterizes the precise moment of transition, the movement towards "modern mining" can be assumed on each occasion where "the skilled miner stepped aside [and] the engineer stepped forward."[35] Once the transition was complete, the success of a mine no longer depended on the skills of the work force, rather it became "a question of how well the engineer [had] designed mining and benefication on the basis of his geological data" prior to the commencement of operations.[36] This change was not based on the use of mechanical devices to duplicate and augment human labour, but on the development of new methods of mining and mineral processing that eliminated human labour in some cases and redefined it in others.

The transition to "modern mining" was gradual, but cumulative. It can be dated from as early as 1859 with the development of square-set timbering on the Comstock Lode in Nevada; even though this method of ground support was designed to facilitate mining by otherwise traditional methods. The appreciation of "square-setting" as a specific engineering response to a particular problem has not been widely recognized although its value as a mining method has.[37] Nevertheless,

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[34](cont'd)York: AIMME, 1947): p. 29.

[35] For example, "In broad terms it may be said that silver mining [beginning with the Comstock Lode and the use of square-set timbering] ended the poor man's day in mining and ushered in the era of the financier and the engineer." Barger and Schurr, *op. cit.*, pp. 101 - 115.

[36] *Ibid.*, p. 115. Benefication refers to the reduction of ores. At the mine site it consists of the milling and concentrating processes. Fay, *op. cit.*, p. 75.

[37] "The advantages of the square-set system in mining large ore bodies were quickly recognized, and the idea spread throughout the world ... As square-set mining became widely known, there was a tendency for years to use the method regardless of its suitability." Gardner, Johnson and Butler, *op. cit.*, 115; see also James F. M. McClelland, "Section 10: Prospecting, Development and Exploitation of Mineral Deposits," in *Mining Engineers' Handbook*, 2nd rev. ed. 2 vols., ed. Robert Peele (New York: John Wiley & Sons, 1927), 1:617.

square-set timbering has been considered "the first important application of the principals of engineering directly to mining, as opposed to the adoption to underground use of techniques originally developed elsewhere."[38] The transition became more apparent as mining became the "large scale, systematic exploitation of low-grade mineral deposits, both underground and on the surface."[39] Thus, the transition to modern mining was not only closely associated with the rise of the professionally trained engineer but with the gradual transition from selective to non-selective, or bulk, methods of mining.

The growth of the copper industry in the Western Cordillera was closely associated with the development of efficient rail transportation and the entry of large corporations into the business. The major copper producing centers in the United States prior to 1900 -- Butte, Montana and the Arizona copper camps - were all spurred on by rail transport as much as by the presence of copper ores.[40] As the railways began to penetrate the cordilleran region in depth after 1880, mines in the region began to shift their production emphasis away from gold and silver bullion and towards the bulkier base metals. In effect, the change in product was an indication that the remote mining regions were being integrated into national and international industrial economies. At the same time, the smaller companies concerned with quick profits in precious metals that had dominated western mining prior to 1880 began to be replaced by larger, externally based corporations intent on long term, extensive

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[38] Barger and Schurr, *op. cit.*, p. 101.

[39] *Ibid.*, p. 57.

[40] For Butte, see Michael P. Malone, *The Battle For Butte: Mining and Politics on the Northern Frontier, 1864 - 1906* (Seattle: University of Washington Press, 1981), pp. 23 - 24. The early histories of the Arizona copper camps are described in Parsons, *The Porphyry Coppers, op. cit.*: for Bisbee see pp. 301 - 307; Morenci, pp. 100 - 103; and Globe, p. 186.

production.[41]

While selective mining methods produced a high-grade ore, as a mining method it was unable to provide sufficient production to meet the demand for metals or profits in all but the richest mines. The situation was such that at the same time that production was being consolidated in the hands of a few large corporations there was also a growing belief in the mining community that North America's copper resources were nearly depleted.[42] This combination of increasing capitalization and apparently dwindling resources at the turn of the century encouraged the copper industry to move towards the utilization of lower-grade ores -- a situation which precluded spectacular returns on investment and relied instead on increased volumes rather than higher qualities in the operations of mines. It also encouraged improvements in concentrating methods, not only to increase the rate of recovery of copper but to derive an income from gold and silver which had become by-products of copper production.[43]

At first the shift from selective to non-selective mining meant taking less care with the mining process. Power drills and high explosives were increasingly used in the ore itself which produced higher volumes of diluted ore. In the concentrators the resulting lower grade ores were accommodated by processing it several times by the

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[41] Before 1880, the largest percentage of mining ventures in the western United States was locally financed and closely held. The penetration of New York, Boston, and London capital reflected the increasing integration of the western mines in the national economy as did the increased production of base metals. Paul, *op.cit.*, p. 154. See also Navin, *op. cit.*, p. 111.

[42] F. E. Richter, "The Copper-Mining Industry in the United States, 1845 - 1925," *Quarterly Journal of Economics* 41 (February 1927): 264; and Louis Shattuck Cates, "Introduction," in *Seventy-Five Years of Progress, op. cit.*, p. *viii.*

[43] Barger and Schurr, *op. cit.*, p. 107; and Navin, *op. cit.*, p. 111.

prevailing gravity methods whose recovery rates had not been significantly increased.[44] The increased reliance on lower-grade ores encouraged a greater cost consciousness throughout the mining and milling processes. For example, in 1901 and 1902, the Granby Corporation's Phoenix Mine in the Boundary District of British Columbia carried "underground non-selective mining to its logical conclusion by mining copper of the then incredibly low average grade of 1.35 percent with no regard to selection beyond mining within the margins of mineralization."[45] The necessary cost reductions needed to make this grade of ore profitable were gained by re-engineering the mining system to eliminate the use of square-set timbering which had engaged fully one-quarter of the mine's underground work force in 1900, and by adopting a non-selective method called block-caving which further reduced the size of the underground workforce.[46] Further cost reductions were realized through the economies of scale associated with the treatment of large volumes of ore. Consequently, a copper property that had initially been considered marginal with favourable copper prices was made profitable even after the price of copper fell by more than one-third.[47]

Efforts to exploit low-grade copper deposits were further advanced by the developments in Bingham Canyon, Utah. This area had originally opened as a gold and silver camp in 1864 with the presence of copper noted in veins and in widely disseminated porphyry deposits. Copper mining by then conventional methods

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[44] Taggart, *op. cit.*, pp. 99 - 101; and Chapman, *op cit.*, p. 1.

[45] Granby had the added advantage of mining direct smelting ores, that is ores that did not require further concentration on the surface before being treated in the smelter, thus avoiding one costly step in the process. Julihn, *op. cit.*, p. 131.

[46] British Columbia, Minister of Mines [hereafter BCDOM], *Annual Report, 1902*, pp. 1052 1054; *1903*, pp. 175, 177; see also Larry Ernest Carter, "Granby: Severty-five Years of British Columbia Copper Mining" (B. A. Honours essay in geography, University of British Columbia, 1979), p. 19.

[47] BCDOM, *Annual Report, 1903*, p. 24.

commenced on the high-grade veins in 1896. Plans to develop the property as an open pit mine based on high volumes as opposed to high grades were originally rejected in 1899 and then put into operation in 1906-07. The experiment proved a success even though the recovery of copper from the ore was no greater than 75 percent.[48] The success of Utah Copper's Bingham Canyon project was copied by the Nevada Consolidated Company at its Ely, Nevada mine. By 1910, these two open pit mines accounted for 24 percent of the copper ore mines and 14 percent of the total copper produced in the United States.[49]

The early success of open-pit copper mining was based on the economies of scale inherent in mass production techniques and greatly reduced labour costs when compared to techniques employed in underground mines. The use of rail-mounted steam shovels and full sized railway cars to load and move ore from the pit to the concentrator meant that fewer people were involved in the loading and transportation of the ore. While shovel operators were highly skilled and well paid in comparison to common labourers there were few people in those positions. Compared to underground mines where a larger percentage of the labour force was involved in breaking ground and timbering -- activities that required a certain degree of skill -- in the open-pits most workers were involved in the less skilled jobs of transporting ore and waste rock.[50]

The porphyry copper deposits were also mineable at depth through the use of

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[48] Parsons, *The Porphyry Coppers, op. cit.*, pp. 44 - 96. See also Leonard J. Arrington and Gary B. Hansen, *The Richest Hole on Earth, A History of the Bingham Copper Mine* (Logan, Utah: Utah State University Press, 1963), *passim.*

[49] Leong, *et. al., op. cit.*, pp. 26 - 27.

[50] Gardner, Johnson, and Butler, *op. cit.*, pp. 126 - 140; Leong, *et. al., op. cit.*, p. 29; and Navin, *op. cit.*, pp. 118 - 121.

block-caving techniques adapted from the iron mines of Wisconsin and Michigan.[51] The method was first used in the United States at the Ohio Copper Mine in Bingham Canyon, again in 1906.[52] The successful application of the method required precise geological definitions of the ore body and a high degree of precise engineering before mining commenced. Once the area to be mined was closely mapped, it was cut free from the surrounding waste rock and undercut. Thereafter, gravity instead of explosives was relied upon to break the ore. An often elaborate system of tunnels and drawpoints was required to remove the broken ore which, like open-pit mining, shifted the manpower emphasis in the mine from breaking ore to transporting it.[53]

Improved mine transportation systems were important to the success of both open-pit and block caving techniques. The matter was especially critical in underground applications where it was difficult to freely adapt the tools and methods of general surface construction. The need to move large tonnages underground encouraged the redesigning of flow-systems to reduce to a minimum the amount of handling required as well as increased mechanization to reduce the labour costs involved.[54] The systems of organization and economy employed in mining the porphyry coppers were adopted, in so far as possible, by other mines in an effort to remain cost competitive with the

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[51] Many of the innovations in copper mining were adopted and modified to local conditions from then recent changes in practice in iron mines which were also becoming increasingly dependent on mass production to sustain their economic viability under conditions of chronic oversupply and reduced prices. Block-caving was first used in North America at the Pewabic mine on the Menominec Range around 1895. See N. Yaworski, O. E. Kiessling, C. H. Baxter, Lucien Eaton and E. W. Davis, *Technology, Employment, and Output Per Man in Iron Mining*, National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques Report No. E-13 (Philadelphia: Work Projects Administration, June 1940).

[52] Gardner, Johnson, and Butler, *op. cit.*, p. 115; and Chas. F. Jackson, "Metal Mining Practice over 60 Years," *Canadian Mining Journal* 60, 11 (November 1939): 673.

[53] Jackson and Hedges, *op. cit.*, p. 238; and Leong, *et. al., op. cit.*, pp. 99 - 105.

[54] Leong, *et. al., op. cit.*, p. 114.

open-pit mines. When solutions could not be found in the design of a mine due to geologic restraints, attention was directed towards increased recovery in the milling process or greater productivity in the labour force.[55]

"Mining, to be precise, ends when the ore is delivered to a bin outside the mine;"[56] but, since ores are defined in terms of their potential to be mined at a profit, the next step in the processing -- milling and concentrating -- is critical to the definition of an ore.[57] Even though gravity concentration methods had been improved over the fifty years of intense growth in mining, a significant percentage of metal continued to be lost in processing. The mining of lower grades of ore placed a strain on the technology of the early 1900s. The initial responses were to increase the size of the mills and increase the number of times the ore was passed through the system. In the first decade of the century a typical concentrator resembled "a timber maze through which pulp [the ore being treated], operators, and superintendents seemed to pursue each other in an endless chase."[58]

The separation of the ore from the waste was conducted in a curious blending of hand-sorting and mechanical means. Depending on the complexity of the ore, hand-sorting might occur three or even four times before the ore was finally given up to the shaking tables. Even though no one sorter would process more than two tons of ore per shift, the application was universal for all high-grade ores before

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[55] *Ibid.*, p. 23.

[56] A. B. Parsons, *Porphyry Coppers, op. cit.*, p. 429.

[57] William Young Westervelt, "Section 25: Mine Examinations, Valuations, and Reports, Article 14: Operating Scale and Profits, Capital Requirements, Amortization," in Peele, 2d re. ed., *op. cit.*, 1: *1734*; and Officers of the Department of Mines, *An Introduction to Metal Mining in British Columbia*, B. C., Department of Mines Bulletin No. 17 (Victoria: BCDOM, 1943), p. 16.

[58] Taggart, *op. cit.*, p. 117.

1913. In addition, many of the mechanical sorters required close attention by a sizable labour force capable of recognizing waste rock from mineral.[59]

Initially, the increased volumes of ore generated by non-selective mining methods were accommodated through increased mechanization of the milling process. Since there was a smaller amount of high-grade ore to handle, hand-sorting was generally eliminated. Labour intensive stamp mills, the mainstay of nineteenth crushing technology, were replaced with jaw crushers and grinders which greatly increased the supply of sized ore to the gravity separators. The increased use of these devices and the larger volumes passing through the mills accentuated an old problem: the presence of ore bearing particles -- slimes -- that were too small to be recovered by differences in specific gravity and were consequently lost.[60]

Mill losses due to sliming was a common problem in precious and base-metal operations. In the closing years of the nineteeth century, the McArthur-Forrest cyanide process revolutionized the concentrating of gold and made mass processing of chemically complex precious-metal ores a reality by abandoning gravity separation altogether in favour of dissolving the gold in a solution for later recovery by percipitation. The problems of over-grinding were avoided since slimes responded well to cyanidization. Mill losses were reduced, recovery from complex ores was increased, and the amont of gold present in a mine necessary to produce a profit was redefined.[61]

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[59] S. J. Truscott, *A Text-Book of Ore Dressing* (London: Macmillan and Co., 1923), pp. 23 - 35; Taggart, *op. cit.*, "Table 2, Developments in Separation," pp. 114 - 115; and Chapman, *op. cit.*, p. 2.

[60] C. S. Parsons, "Sixty Years of Development in Ore Dressing," *Canadian Mining Journal* 60, 11 (November 1935): 693.

[61] Charles F. Jackson and John B. Knaebel, *Gold Mining and Milling in the United States and Canada: Current Practices and Costs*, U. S., Bureau of Mines Bulletin No. 363 (Wasington D. C.: USGPO, 1932), pp. 50 - 91, 112 - 117; see also A. W. Allen, "Early History of the Cyanide Process, Part 1," *Engineering and Mining Journal* 124, 10 (September 3, 1927): 371 - 374; "Part 2," 124, 14 (October 1, 1927): 528 -

Whereas improvements to the traditional methods of gravity concentration had slightly increased recovery rates and increased recovery problems, the cyanide process redefined the grade of ore worth treating and the methods by which it was done.[62]

The solution to the problem of copper losses in concentration did not stem directly from the application of the cyanide process, though it was tried. Still, the solution did stem from the focused attention of chemists and engineers either directly employed by or under contract to mining companies. For years the low rates of recovery had plagued the silver-lead-zinc mines of Broken Hill, Australia. For example, in 1903 the Block 10 Mine raised ore to the surface with an assayed value of £380,000 which paid £90,000 after treatment. More than half the silver in the ore and almost all the zinc was lost. Lead presented the best recovery rate with only one-third being lost.[63] Between 1900 and 1906 an intensive effort was made to recover the zinc from the Broken Hill ores by the mining companies involved. Their attention focused on the development of a practical flotation process which would reverse the normal gravity process and float off light particles of ore. After numerous laboratory successes and practical failures the Elmore oil flotation process was made to work under production conditions and turned the waste heaps of the region into zinc mines in their own right.[64]

The flotation process was only gradually accepted in North America. Since flotation was considered to be a lead-zinc process it was first used successfully by the

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[61](cont'd)532; and "Part 3," 124, 15 (October 8, 1927): 560 - 574.

[62] Barger and Schurr, *op. cit.*, p. 152.

[63] Geoffrey Blainey, *The Rush That Never Ended: A History of Australian Mining*, 3rd ed. (Carlton, Victoria: Melbourne University Press, 1978), p. 259.

[64] T. A. Rickard, "The History of Flotation," in his *Concentration by Flotation* (New York: John Wiley and Sons, 1921), pp. 9 13.

Butte & Superior Copper Company to treat those ores in 1911 or 1912.[65] Over the next three years flotation was cautiously introduced in the larger copper concentrators as an ancillary process to gravity separation where it was used to treat mill tailings and previously useless slimes. By 1918, flotation was being used with greater frequency as the benefits of integrating the process with the improvements in grinding methods became apparent; instead of using it to handle only the rejected ore from other processes, more and more of the ore was fine ground and fed to the flotation units. Still, the general elimination of gravity concentration for copper did not occur until 1923 - 1927. Once gravity methods were dispensed with entirely and selective flotation was developed, recovery rates in excess of 95 percent became common, even with complex ores.[66]

The general acceptance of flotation was retarded in part by ongoing law suits over copyright infringements which, while they delayed the general acceptance of the Elmore patents owned by the Minerals Separation Company, encouraged experimentation in flotation so as to change the process sufficiently to avoid the consequences of an unfavourable judgment.[67] Once the legal problems had been settled in the mid-1920s, flotation became the primary means of concentrating copper ores and redefined the nature of work in the mills. Larger mills with simplified flowsheets became the rule.

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[65] Blainey, *op. cit.*, p. 270, dates the first use of flotation in North America from 1911. Chapman, *op. cit.*, p. 2, suggests that there were several unsuccessful efforts made in 1906 and 1911, and that the Butte & Superior success came in 1912. Even earlier efforts were made to adapt the Elmore process to Rossland ores over several years beginning in 1902. See "Rossland Ores and the Elmore Process," *British Columbia Mining Record* 9, 7 (July 1902): 223 - 224; and H. H. Claudet, "A Pioneer Flotation Process," *Western Miner and Oil Review* 27, 5 (May 1954): pp. 35 37.

[66] Chapman, *op. cit.*, pp. 3 - 4, and Table, p. 9.

[67] T. A. Rickard, "Flotation Litigation, I & II," in his *Concentration by Flotation, op. cit.*, pp. 100 - 136.

Mill capacity could be increased by simply adding additional units beside those already in operation without interfering with them. Flotation mills were built in selfcontained units or parallel sections with independent flows so that it was no longer necessary to shut down an entire mill to repair one section of it. Finally, flotation lowered repair costs since fewer parts had to be stocked or made.[68]

The impact of flotation on the mill labour force was considerable. "The direct effect of increased section capacities [was] a marked increase in tons of ore treated per man shift with a corresponding reduction in operation labour, repair labour, and overhead costs per ton of ore concentrated."[69] With the passing of the gravity mills, a comparative sense or order replaced the earlier chaos, and:

> The operators can keep most of the machines for which they are responsible in sight at all times, and the superintendent's office can be and is placed so as to afford him a reasonably complete vista of at least the entire concentrating plant.[70]

The increases in productivity brought about by the use of mass production techniques and the further mechanization of copper mining reduced the total number of jobs available in mining and concentrating. Until 1917, the size of the work force increased in direct proportion to the output of copper. Thereafter, production levels were maintained until 1930 -- except during the post-World War depression -- while overall employment declined by nearly one-half. For example, in 1917, United States production of new copper was nearly 2 billion pounds and 61,275 people were employed in the mines. By 1929, production levels had increased marginally over the

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[68] Taggart, *op. cit.*, pp. 117 - 120, and "Table 5, Developments in Mill Design and Operations," p. 121.

[69] Chapman, *op. cit.*, p. 18.
[70] Taggart, *op. cit.*, pp. 117 - 118.

1917 level while the work force had decreased to 37,147. Furthermore, the number of man shifts worked had decreased from 19,086,000 to 11,984,000. The gains in labour productivity and the maintenance of production levels had been achieved despite the mining of progressively leaner ores which meant that more ore had to be mined and processed. The 1917 production was derived from approximately 59 million short tons while slightly less than 68.5 million short tons of ore were mined and processed in 1929.[71]

The re-engineering of mining affected both skilled and unskilled employees. The "all-round miner" or "jack-of-all-trades" was replaced by men trained for specific tasks; and the numbers of unskilled who had previously been engaged in digging, shovelling, picking, and sorting were reduced as mechanical loaders, scrapers, and better designed systems of moving ore were introduced in underground mines. The design and execution of mining operations had become an engineering problem to be solved in the offices and on the drafting tables; they were no longer the concern of the skilled miner at the working face. Miners no longer performed a wide variety of tasks, rather their jobs were tightly defined by the engineering staff in standardized instructions administered and supervised by experienced foremen.[72]

The engineering concern with costs, efficiency, and productivity was not restricted to the design and implementation of mining and milling systems. Wherever possible, it was extended to the level of the individual worker. Efforts to that end were intimately tied to the often disruptive question of wages with the full comprehension that "While improved technology is an aid to reduction of mining costs,

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[71] Leong, *et. al., op. cit.*, pp. 179 - 180, "Table 5, Production, Employment, Manshifts, and Unit Labor Requirements in Copper Mining," p. 180, and "Table A-1, Production, Employment, and Output per Worker at Copper Mines, 1880 - 1936," pp. 214 - 215.

[72] Leong, *et. al., op. cit.*, pp. 181 - 182.

the ability of the manager to devise ways and means of encouraging labour to accomplish more per hour without reducing wages is of greater importance."[73]

Unlike the Michigan copper mines which were worked on a contract basis, hourly or daily wages were the norm in the western mines before 1900.[74] Efforts to reduce wages as a response to falling metal prices or company profits were frequently resisted with strikes that did little to improve the short term prospects of the mines being struck. The first efforts to reorganize payments systems came with Anaconda Copper's proposal of a sliding scale: above a certain minimum, wages would be tied to the price of copper and would rise and fall accordingly. The proposal was accepted by the Western Federation of Miners and their Butte affiliates in 1907.[75] The intent of this measure was to tie the fortunes of the miners to those of their employers and shift a portion of the entrepreneurial risk onto the workforce. During the 1920s, the "copper bonus" became a standard item in the determination of wages in copper mining.[76]

Efforts were also made to control costs and encourage greater worker productivity by adopting contract or piece-work systems of payment. The experience of the Michigan mines suggested that

> Contract systems tend to promote speed, reduce unit costs, and diminish expense of supervision; and a contractor generally obtains better returns with shorter working hours than a day

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[73] Charles Will Wright, *Management of Labor in Successful Metal-Mine Operations*, U. S., Bureau of Mines Information Circular No. 6655, August 1932, p. 2.

[74] United States, Department of Commerce and Labor, Bureau of the Census, *Special Reports, Mines and Quarries, 1902* (Washington, D. C.: USGPO, 1905), Table 8, p. 45.

[75] Jensen, *op. cit.*, p. 303.

[76] *Engineering and Mining Journal 127 (February 23, 1929): 333.*

> laborer. Operator can count with certainty on ultimate cost of a given undertaking, while contractor is free to reap reward of his energy and skill.[77]

The contract system also had its less attractive qualities. Besides strong resistance by individual workmen and their union organizations, standards of performance were difficult to enforce since the contractors' motives made him "a class of workman whose interests do not exactly coincide with those of the company."[78] Contracts were reasonably easy to assess and control in the areas of mining that could be measured in linear feet such as tunneling and driving raises; but when the unit of measure was tonnage as in the removal of ore in the stopes, it was often difficult to maintain acceptable grades of ore as the contractor was apt to include significant quantities of waste rock to raise his income.[79]

The method of payment that finally gained acceptance from both employer and employee was a modified contract or bonus system.[80] The bonus system established minimum daily or monthly tasks and wages to be paid on the same basis. Any work performed in excess of these minimums was paid for at an additional rate "so computed that the employer shared in the savings in operating cost, besides profiting from more rapid work."[81] The determination of standards for minimum tasks acceptable to both management and labour was made possible by the keeping of detailed records on production and the costs associated with specific jobs. It was in the design and implementation of the bonus system that mining engineers became directly and

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[77] Edward K. Judd, "Section 22: Wages and Welfare," in Peele, 2d rev. ed., *op. cit.*, II: *1529.*

[78] *Ibid.*

[79] *Ibid.*

[80] Gardner, Johnson, and Butler, *op. cit.*, pp. 252 - 253.

[81] Judd, *op. cit.*, II: *1530.*

explicitly involved in human engineering.

At larger mines, bonuses were calculated within a larger planning department which collected highly detailed records of prior performance and set bonuses for each particular job so that they were neither too large nor too small. Smaller mines often relied on the practices of their larger neighbours in setting bonus rates in order to keep their wages competitive. Generally, a basic day rate was provided to all employees which negated the major complaints about the pure contract system, and the bonus payment was set at a level calculated to encourage the workmen to exceed the standards set by the bonus engineer.[82] During the teens and twenties the system was widely adopted in various forms and under a variety of names. In practice, the terms "contract" and bonus" were used interchangebly with the common denominator being the guarantee of a base wage.[83] As standards were established the bonus system was extended to encompass much of the work done in and around the mines. For example, by 1932, the majority of the underground work and all of the mechanical and open pit work was on a bonus system in the mines of the southwestern United States. The reason set forth by the copper mines in Arizona was simple: "The Company gets the work done at a certain fixed price whether the miner makes a good bonus or not."[84]

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[82] Wright, *op. cit.*, p. 8.

[83] *Ibid.*

[84] *Ibid.*

Mining and Milling Operations at the Britannia Mines, 1898 - 1937

The inherent value of case studies to uncover the nature and direction of technological change in the mining industries has been questioned in the work of Ronald C. Brown. After observing that few western mines adopted major technological innovations as they became available, he concluded as a major assumption of his study of mining labour that: "Mining was an undertaking in which the stage of development of a given mine was more closely related to the time interval since its discovery than to the state of industrialization of the occupation as a whole."[1] Mines, therefore, were seen as set pieces which exhibited the available technology of the time they were placed into production; and it was strongly suggested that they did not significantly deviate from the system of mining, processing, and management first installed. In many of the short-lived, high grade mines that characterized the nineteenth century this observation may well have been generally true even though the assumption is in conflict with models of technological change that stress innovation as "a series of smaller and highly tentative steps" rather than the dramatic "displacement of one technique by another."[2] Even the experience gained from technical practice in short-lived mines could and did contribute to larger changes in the industry.

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[1] Ronald C. Brown, *Hard-Rock Miners: The Intermountain West, 1860 - 1920* (College Station: Texas A&M University Press, 1979), p. *xiv*.

[2] Nathan Rosenberg, "Factors Affecting the Diffusion of Technology," *Explorations In Economic History* 10 (1973): 8, 33.

Nevertheless, in marginal mines or those working small ore bodies or showing consistently poor financial returns it is unlikely that major investments in new techniques would be routinely made, although it is doubtful that no change in practice, whatsoever, occurred. The set piece view of mining operations is even less tenable in the twentieth century when one of the hallmarks of mining operations and particularly copper mining became the intensive exploitation of large masses of lower grade ores over an extended period of time. Under such conditions it becomes highly reasonable to expect significant capital reinvestment to take place from time to time in order to keep the mine competitive as geological conditions and market structures changed. Furthermore, the same expectation can be supported if new investment carries a sufficient potential to reverse the declining fortunes of an unexhausted ore body or enhance profits by reducing costs and increasing productivity in a highly competitive market.[3]

Active exploration at what was to become the Britannia mines began late in the winter of 1898 and production extended from 1905 until 1974 with only a few short suspensions of activity. During the first thirty years of operations there were three periods of major capital investment which propelled the property, by 1929, to the rank of the largest copper producer in the British Commonwealth. After 1911, when the first major technical and managerial reorganization began, the thrust of change in practice and equipment was directed towards increasing the efficiency of the overall operation and integrating labour and technique into a balanced and cost effective system of mining, transportation, and ore processing. By the 1930s continued exploration and the acquisition of adjoining mineral claims extended mining operations

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[3] Homer Aschmann, "The Natural History of a Mine," *Economic Geography* 46 (1970): 180 - 181; Nathan Rosenberg, "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices," in his *Perspectives on Technology* (London: Cambridge University Press, 1976), p. 124; and William C. Peters, *Exploration and Mining Geology* (New York: John Wiley & Sons, 1978), pp. 216 - 221.

across five major ore bodies -- the Jane, Bluff, Fairview, Empress, and Victoria -- and provided a continuing resource base for the mine in a variety of geological conditions.[4] Since the initial exploration and development of the mines began during the early stages of the transition to "modern mining," the nature of that change can be demonstrated in detail as it unfolded through successive production and management systems at Britannia. While such a specific record cannot be used to establish a definitive chronology for change in the overall copper mining industry, technical practice at the Britannia mines and its relationship to labour usage can illustrate the general shift to mass mining and processing in an underground mine with its attendant redefinition of work in the years between 1900 and the depression of the 1930s.

The Britannia mineral zone is located along the eastern edge of Howe Sound approximately thirty miles north of Vancouver, British Columbia.[5] The topography of the region is rugged and the sharp ridges of the Coast Range rise to elevations of four and five thousand feet within a few miles of tide water. While the nature of the terrain was evident to the casual observer, geological information on the region was only obtained as a result of mining operations. By the late 1920s the consensus of opinion was that the Britannia zone was a part of the Pacific mineral belt which paralleled the western edge of the Coast Range batholith, a massive plutonic intrusion which defined the two major hard rock mining regions in western British Columbia. To the east of the batholith gold, silver, and lead deposits provided the material basis for the Pioneer, Bralorne and Premier mines which prospered during the 1930s. The western side, the Pacific mineral zone, was characterized by massive copper deposits exploited as the Britannia mines, the Hidden Creek mine at Anyox, and, more

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[4] For a general overview of the Britannia mines see Marilyn Mullan and Dianne Newell, "Britannia Mines Concentrator: Canada's Largest Museum artifact," *CIM Bulletin* 77, 868 (August 1984): 74 - 76.

[5] See Appendix A, Map 1.

recently, the Island Copper Mine on Quatsino Sound.[6]

Despite Howe Sound's close proximity to Vancouver and easy water access from Victoria, the area received little sustained attention from mining promoters until the end of the nineteenth century. During the 1870s and 1880s prospecting around the Sound was focused on the search for precious metals which propelled so much of the the nineteenth century's mineral exploration. Only small, noncommercial deposits of gold and silver were located, and the more abundant indications of copper were largely ignored due to copper's low value relative to gold.[7] There were two small copper excitements centred on the Sound, but little came of them. The first was in 1868 when reports of a mine of great potential, and vague location, circulated briefly in Victoria. The second involved a small prospect tunnel on Mount Elphinstone that was promoted without success by the Oppenheimers of Vancouver in the early 1880s. The disinterest in copper was so general that Dr. A. A. Forbes, the initial locator of the Britannia claims, was unable to attract any investors with the property even though he had sunk a short shaft and obtained several impressive samples.[8] The emergence of Rossland as a major copper-gold field during the 1890s created a strong interest in copper mining throughout the province which led to the opening of the Boundary District as an important producer in 1900; it also encouraged renewed interest in the

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[6] Stuart J. Schofield, "The Britannia Mines, British Columbia," *Economic Geology* 21 (1926): 271 - 284; and H. T. James, *Britannia Beach Map-area, British Columbia,* Geological Survey of Canada, Memoir No. 158 (Ottawa: King's Printer, 1929), pp. 73 - 74, 80 - 110.

[7] British Columbia, Minister of Mines [hereafter BCDOM], *Annual Report, 1874,* p. 36; *1877,* p. 413; *1888,* p. 325; *1899,* p. 811; and James, *op. cit.,* p. 70.

[8] Bruce Ramsey, *Britannia, The Story of a Mine* (Vancouver: Britannia Beach Community Club, 1967), pp. 16 - 17; Oppenheimer Family Papers, Vancouver City Archives, Add. Mss. 108, Vol. 12, p. 9; and "Substance of Interview Between Dr. A. A. Forbes and Messrs. C. P. Browning, W. A. Matheson, and Geo. R. Hurley, April 2nd, 1931," British Columbia Museum of Mining, Curator's Files [hereafter BCMM-CF] Discovery File No. 2.

copper showings on Howe Sound. During the Christmas season, 1898, Oliver Furry staked seven claims on the high ridge south of Britannia Creek which were centred on the area prospected by Dr. Forbes ten years earlier.[9] Soon after, the claims passed into the hands of Boscowitz and Company, a Victoria firm of fur buyers, and exploration work began almost immediately.[10]

Evaluation of the claims was conducted by the then customary manner which emphasized underground exploration and the traditional skills of the nineteenth century miner. A camp was established in the Jane Basin at an elevation of 3,500 feet, and a four mile pack trail was cut to link the camp to Howe Sound and water transportation. While some efforts were made to gain a superficial knowledge of the geology and mineral content of the claims through surface surveys and trenching on the more promising exposures, the primary prospecting work was carried out underground. The general rules for underground exploration at the time were: "(a) Keep working in the ore body; (b) Do first work on best showings, to see whether or not they are superficial; (c) Do the work as cheaply as possible on account of the high risk involved."[11] A small crew was immediately put to work with hand steel and sledges to drill and blast a tunnel across the area of most obvious mineralization. Once this crosscut tunnel had advanced 132 feet into the bluff, the miners started to

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[9] See Appendix A, Map 2.

[10] BCDOM, *Annual Report, 1899*, p. 812; and James, *op. cit.*, pp. 70 - 71. A certain amount of controvery surrounds Furry's "discovery." Evidence suggests that Furry was probably grubstaked by one F. Turner on the basis of information obtained from Dr. Forbes between 1897 and 1898. Turner was definately the Vancouver agent for Boscowitz and Company which might explain the *Annual Report*'s reference to the discovery by "some trappers." Dr. Forbes had not registered his prior discovery since the legal mechanism to do so had not been in place at the time of his initial location. "Substance of Interview," *op. cit.* p. 5.

[11] James F. McClelland, "Prospecting, Development and Exploitation of Mineral Deposits," in *Mining Engineers' Handbook*, ed. Robert Peele (New York: John Wiley & Sons, 1918), p. 442.

drift along what they assumed was the strike of the main vein observed on the surface.[12] The Minister of Mines' *Annual Report* for 1899 treated this work and the entire property rather cautiously. After noting the general excitement surrounding Britannia, the report commented on the exploration work: "... drifting was started, apparently in the belief that ore carrying values had been reached."[13] The caution was justified. While efforts were continued to locate high grade values, rich veins eluded the miners as they continued to penetrate extensive areas of lower grade mineralization.[14]

Despite the failure to confirm copper-gold veins of bonanza qualities, the large, poorly defined body of low grade copper contained small quantities of gold and silver. The results of the first year's work were sufficient to generate further interest in the property in the mining community on both sides of the Canada-United States border. In November, 1899, a syndicate headed by Howard Walters of Libby, Montana and J. A. Adams of Vancouver purchased a seven-tenths interest in the Boscowitz holdings with the understanding that Boscowitz and the syndicate would attempt to secure a purchaser for the entire property. Exploration work was continued for the next two years under Walters in his capacity as managing director of the Britannia Copper Syndicate in order to increase the property's attractiveness. Overall higher grades of ore

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[12] *Ibid.*, p. 460, "Drifting and crosscutting by hand drilling is done in connection with exploratory work in small mines where expense for plant is not justified [sic], and in districts where skilled labor is not available for running machine drills." Note the association between skilled labour and machine drills. Whatever the reason, there is no evidence to suggest machine drills were used at Britannia prior to 1904-05.

[13] BCDOM, *Annual Report, 1899*, pp. 811, 813.

[14] The major description of early work on the Britannia claims is W. M. Brewer, "Prospects on Howe Sound, West Coast," *Engineering & Mining Journal* [hereafter E&MJ] 69, 11 (March 17, 1900): 315 - 316. Brewer's article formed the basis for a number of Vancouver and Victoria newspaper reports and was reprinted almost in its entirity in the *Annual Report, 1899*, pp. 812 - 814. Many details of work on the claims at this stage are not recorded and have been inferred from evidence relevant to later dates and from descriptions of common practice as noted.

and a more precise knowledge of the potential value of the claims were essential if the syndicate was to attract a buyer with the substantial capital required to place the ore body into production.[15]

After the syndicate assumed control of the work on the claims between twelve and sixteen men were steadily employed to pursue underground exploration and surface trenching as the weather permitted. The mining crews were organized into three 8-hour shifts in accordance with provincial law and accounted for the majority of the work-force. The other employees included a blacksmith to keep tools and drill steels in good repair, a horse packer to bring in supplies, and the seasonal labourers who worked ten to twelve hour shifts in the open cuts when there was no snow on the ground. Finally, there was a foreman to coordinate activities, ensure supplies, and communicate orders and information between the camp and the syndicate's office in Vancouver. Each underground shift probably consisted of three men: one or two drillers depending on the hardness of the ground and a helper or a trammer.[16] Their efforts produced the beginnings of a serpentine maze of tunnels as the crews attempted to follow and define more obvious geological features and mine such high grade ores as they encountered. Ores averaging 8% copper with incidences of 25% copper were hand sorted and sacked for immediate shipping to provide some revenue for the syndicate and keep the claims in the public eye. The Vancouver and Victoria newspapers responded appropriately with headlines that read "Mammoth Mine Close At Hand," "Big Things Promised; What The Britannia Group May Mean To Vancouver," and "Rivalling Anaconda."[17]

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[15] James, *op. cit.*, pp. 70 - 71; and BCDOM, *Annual Report, 1899*, p. 811; *1924*, Part B, p. 230.

[16] See McClelland, *op. cit.*, pp. 460 - 461.

[17] "Vertical Section" and "Plan of Jane Main Workings," circa. 1900, BCMM-CF, Discovery File No. 2; BCDOM, *Annual Report, 1900*, pp. 930 - 932; *Vancouver Daily*

As more information was gathered on the nature and extent of the deposit, generalized plans were made for placing the property into production. Since the exploratory work had concentrated on the location of high grade ores, copper values ranging from 4% to 13% with additional values in gold and silver were developed for mining on the Jane claim. The average grade of ore was expected to run around 8% copper and it was anticipated that a direct smelting ore averaging 15% could be produced with a rough hand sorting applied directly at the mine. Surface exposures opened up by trenching reinforced this assumption since the highly oxidized mineralization found there ran from 15% to 25% copper and could be quarried in large blocks. The much larger areas of low grade copper that were being exposed in the tunnels on the Jane claim presented other problems in mining and processing, but these were generally ignored as the syndicate continued to promote Britannia as a high grade property by emphasizing the mineral values contained in the veins structures within the larger area of low grade mineralization. Additional discoveries of gold and silver intermingled with the high grade copper reinforced the idea that at least the Jane claim could be exploited along traditional lines and earn high profits with a minimal investment. Mining engineers who were brought in to provide independent assessments of the workings felt confident in stating that the mine could be made profitable if the area's abundant water power was harnessed, an aerial tramway constructed to transport the sorted ore, and a smelter erected at the Beach for immediate reduction of the ore. The only reservations expressed were based on the problem of defining a sufficiently large ore body to sustain high grade operations. The members of the syndicate felt the solution to this problem would be found through continued development work.[18]

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[17](cont'd)*Province*, January 16, 1900, p. 6; January 17, 1900, p. 7; January 18, 1900, p. 7; February 6, 1900, p. 7; May 30, 1900, p. 5; *Daily Colonist* [Victoria], January 17, 1900, p. 3; February 21, 1900, p. 7.

[18] BCDOM, *Annual Report, 1899*, p. 814; *1900*, p. 931.

Immediately to the east of the Jane workings was the Mammoth Bluff outcrop, a massive body of low grade ore that could not be treated as direct smelting ore. The average grade of 3.84% was considered substandard by the criteria of the day. More importantly, the copper, gold and silver particles were finely distributed among pyrites which caused problems in the smelting process due to the high sulfur content. Concentration by water and specific gravity was a necessary pretreatment to smelting to increase the percentage of copper and reduce the proportion of pyrites. Even so, the Bluff mine was promoted as economical since it could be mined with a minimum cost by working it as an open quarry and drawing the ore off through glory holes. Thus, the additional costs of concentration were dismissed by asserting that quarrying meant production would be limited only by "the will of the operator and the capacity of the equipment provided." Less attention was given to the mechanics of removing the high grade ores from the Jane mine. It was simply assumed that these workings would be advanced with the use of square-set timber which the *Mining and Scientific Press* referred to as the indispensable aspect of "modern mining" as the term was understood at the turn of the century.[19]

The Britannia Copper Syndicate was not the only group of mining promoters interested in copper in the Howe Sound area. Immediately to the south and adjacent to the Britannia claims were the South Valley Properties which were eventually incorporated into the Britannia mines. This area was being prospected and promoted primarily on the strength of the work done on the Britiannia showings. Nevertheless, the area contained significant extensions of the known Britannia zone mineralization; both high grade ores and massive quantites of low grade concentrating ores had been

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[19] "Ideal Elevation and Cross Section; Suggested Plan For Working Mammoth Bluff," circa, 1900, BCMM-CF, Discovery File No. 2; BCDOM, *Annual Report, 1900*, p. 932. Quote attributed to E. C. [Howard?] Walters, Managing Director, Britannia Copper Syndicate; *Mining and Scientific Press* 86, 1 (January 3, 1903): 1.

exposed by methods similar to those used on the Britannia. Similar processing plans were also put forward except it was proposed to quarry the entire deposit with large faces which promised costs as low as 20 to 30 cents per ton. The low costs were based on the complete absence of timbering and drainage systems in the proposed quarry. Like at Britannia, an aerial tramway was proposed to move the ore to tide water for a total cost of 50 cents per ton of ore. Once at the Beach, the ore would be smelted or concentrated as required. The promoters of this property were particularly optimistic in their predictions in that they publicly assumed that the low copper assays would improve as the mine deepened, an assumption which ran counter to the evidence of the adjacent Britannia claims. The South Valley promoters were equally sanguine in their assessment of the labour costs made possible by quarrying as opposed to underground mining: "All labour is produced at low rate in British Columbia as Japanese and Chinese are largely used in that country without prejudice."[20]

Despite continual exploration and the development of rudimentary mining programmes for the property, the Britannia Copper Syndicate was unable to sell the claims quickly. Considerable interest was shown by both British and American investors, and on several occasions the local papers reported that the mines had sold only to retract the stories in a few days. The usual explanations were that the asking price was too high or that while the parties could agree in principle, they could never finalize terms. In one case, the key man in an English syndicate had the bad fortune to die before he could acquire the mines.[21]

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[20] "Report by Robert H. Hunter, M. E. on So. Valley Properties, Nov. 25th 1900," Britannia Mining and Smelting Co., Ltd., Papers, Provincial Archives of British Columbia [hereafter PABC], Add. Mss. 1221, 114/1, p. 2.

[21] *Province*, July 16, 1900, p. 2; July 27, 1900, p. 3; February 19, 1901, p. 1; August 7, 1901, p. 1; *Colonist*, July 6, 1900, p. 2; July 15, 1900, p. 1; September 2, 1900, p. 3; September 12, 1900, pp. 4, 5; January 1, 1901, p. 6; February 19, 1901, p. 8;

A more reasoned assessment of the failure of the syndicate to sell the property was put forward by the *British Columbia Review* of London which provided British investors with a regular assessment of mining opportunities in the province: "... the price asked for the property was out of proportion to its intrinsic value, so far as present development shows. The mine, or more accurately speaking, the prospect, is extremely low grade, averaging somewhere about $5 per ton."[22] Undaunted, Walters and Adams continued to assess funds from the members of the syndicate to finance efforts to define a viable ore body; and in 1901, $20,000 was spent on continued surveying and prospecting.[23]

During the first three years of work on the property, first under the direction of the Boscowitz interests and then under Walters and the syndicate, exploration was conducted in a promotional manner using traditional mining techniques. The small underground labour force was used to prove or disprove judgemental assumptions about the ore body made on the basis of surface observations. Reliable information about the composition and extent of the deposit was only obtained as the tunneling operations actually penetrated it. Visiting engineers who came to assess the mines also confined their observations to "ore in sight" which quite literally meant ore that could be seen. Since the miners continued to uncover areas of high grade mineralization, impressive assay results were obtained which gave little indication of the average grade or the actual tonnage of ore involved. Nevertheless, all concerned felt confident in producing glowing reports on the mine's potential. Similarly, generalized schemes which reflected the possibilities of greatly reduced operating costs were put forward for mining, transporting, and processing the ore. The enthusiasm for large scale, low cost

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[21](cont'd)August 11, 1901, p. 2.

[22] *British Columbia Review* 3, 196 (January 12, 1901): 14.

[23] BCDOM, *Annual Report, 1901*, p. 1120.

mining was genuine but the overall understanding of the principles involved was limited. Consequently, the proposals were more successful in creating a favourable investment climate than in assessing costs and potential earnings with any degree of accuracy.[24] These investigations and projections were quite successful in creating interest in the Britannia mineral belt, and the area around the Britannia claims was heavily staked by other mining companies during 1900. Interest in the Howe Sound region continued throughout 1901 even though the major successes in copper mining were in the interior Boundary District which was dominated by the Granby and British Columbia Copper Corporations.[25]

The Britannia claims finally changed hands in August 1901, when an investment syndicate headed by George H. Robinson of Butte, Montana, and Henry Stern, a New York investor, gained controlling interest in the Britannia syndicate. Robinson's involvement in the Britannia claims was considered a positive step forward for the property by local commentators since he was rumoured to be the manager of the Montana Ore Purchasing Syndicate and a close associate of F. Augustus Heinze of Butte who had demonstrated his technical skills on numerous occasions as an expert witness during the "War of the Apex."[26]

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[24] It is important to note that costs and earnings were difficult to estimate; and it is the degree of caution rather than the degree of accuracy that is important here. Costs varied greatly from mine to mine and reliable estimates of total costs and revenues on a given property were difficult to obtain except through actual operating experience unless there was an operating mine very close by that was willing to share such information with a new enterprise. While a wide variety of schemes were put forward from time to time, most cost figures were derived from data obtained from actual practice rather than projection. See J. R. Finlay, "Cost of Mining," in Peele, ed., *op. cit.*, pp. 1282 - 1355. Twenty-five examples including five copper mines are discussed.

[25] Brewer, "Prospects," *op. cit., passim.*; *Province*, January 17, 1900, p. 7; Febraury 23, 1900, p. 3; July 16, 1900, p. 2; *Colonist*, July 6, 1900, p. 2; BCDOM, *Annual Report, 1900*, p. 930; *1901*, pp. 932, 934, 1120.

[26] Robinson was actually the chief engineer for the Montana Ore Purchasing Company. F. L. Sizer, "The late George H. Robinson," *Mining Record* 13; 7 (July 13, 1906): 279. The nature of his association with Heinze is unclear since he is not given any

Within a year Robinson and Stern gained complete control of Britannia for their own group of investors by purchasing the 30% interest which had been retained by Boscowitz and then reorganizing the syndicate along more formal lines as the Britannia Copper Syndicate Limited. The financial backing for the consolidation of ownership was provided by Stern who underwrote the stock of the new syndicate with the support of Grant B. Schley, a partner in the New York investment banking firm of Moore and Schley. Schley's involvement put the new syndicate in close contact with the New York capital market. In 1899, the financial capabilities of Moore and Schley had been demonstrated when the firm underwrote and participated in the initial organization of the American Smelting and Refining Company (ASARCO) with a nominal capitalization of $65,000,000.[27]

Under Robinson's control the Britannia syndicate was still interested in selling the property if the proper buyer could be found, but given their greater access to capital they were also willing to continue exploration programmes on the property and place it into production if necessary.[28] Robinson had been directly involved in the management of mines and smelters since at least 1880 and brought considerable expertise to the Britannia investment. He placed considerable emphasis on his practical experience and personal judgement and, on that basis, may be considered a prime example of the traditional mining engineer.[29]

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[26](cont'd)place of prominence in the literature on Hienze and the extralateral rights issue. See, for example, Sarah McNelis, *Copper King At War: The Biography of F. Augustus Heinze* (Missoula: University of Montana Press, 1968). The only mention of Robinson is a photo caption on page 102.

[27] *Province*, August 7, 1901, p. 1; August 9, 1901, p.1; May 19, 1902, p.3; July 26, 1902, p. 1; *Colonist*, August 11, 1901, p. 2; June 3, 1903, p. 6; James, *op. cit.*, pp. 24 - 26; and James E. Fell, Jr., *Ore to Metals: The Rocky Mountain Smelting Industry* (Lincoln: University of Nebraska Press, 1979), pp. 221 - 224.

[28] Kendell to Sawyer, October 14, 1903; Robinson to Humphreys, November 6, 1903; and Sawyer to Robinson, November 27, 1903; PABC, Add. Mss. 1221, 114/5.

[29] Robinson was largely self taught; his experience had been gained in the service of

For example, when a Scottish laboratory failed to confirm his observations on the nature and value of the Britannia ores, he cited his own experience and judgement as sufficient reason to disregard the laboratory reports in favour of onsight inspections he had commissioned which were more in line with his own assessments:

> I have mined and treated about 1,000 tons of ore per day during the greater part of the past twenty years in the capacity of manager and Superintendent, and during that time have not made a failure, hence I have some confidence in my own judgement as to mines and to working qualities of ores. I have examined the Britannia mine and reduced the ore and have invested a considerable sum of money in the property. I have also had two reports made by prominent engineers to check my results.[30]

Robinson's self-assurance supported a highly personal approach to engineering and management in general. As managing director of the Britannia Copper Syndicate Limited, Robinson had control of a property which he assumed to be of great value, even though he accepted that it was primarily a low grade deposit. To offset the higher costs associated with low grade ores he felt that the mine's location close to tide water would allow a profit nonetheless since transportation costs to world copper markets would be comparatively low.[31] It remained for Robinson to balance the grade of the ore with the costs of mining and processing to produce a profit for himself and his investors.

The glowing projections of a high grade bonanza put forward by the original syndicate were rejected out of hand by Robinson. His own initial evaluation of the

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[29](cont'd)the railroads, the United States Geological Survey, and through active participation in mines in Colorado, Utah, and Montana. For a brief biographical sketch, see Sizer, *op. cit.*, pp.278 - 279.

[30] Robinson to Humphreys, November 6, 1903, PABC, Add. Mss. 1221, 114/5.

[31] BCDOM, *Annual Report, 1902*, p. 255.

Britannia property was based on sampling techniques designed to determine minimum ore values rather than the high assays that the original syndicate had sought for promotional purposes. While his observations were still confined to ore "in sight," or the exposed portions of the veins uncovered by the miners' tunnels his efforts to establish average grades indicated a more realistic and pragmatic approach to the property as a potential mine rather than an investment vehicle. The low-grade Mammouth Bluff ore was averaged at 2.57% copper with a gold and silver content of $2.30 and $0.40 respectively. The Jane claim was divided into two categories: high-grade ores which could be shipped directly to a smelter and the lower grade ores which would require concentration before it left the property. Approximately ten percent of the exposed ore was determined to contain 12% or more copper and overall the ore was expected to carry values of 4 to 5% copper which meant that almost all the Jane ores were direct smelting. Estimates of total available tonnage were also made for the first time. Consequently, the grade of ore could be placed in a context that allowed Robinson to estimate a return on investment. All told, the massive low-grade Mammouth Bluff deposits meant that the ore from the Jane accounted for little more than one-twentieth of the ore in sight. Thus, if Britannia was viewed as a high grade mine, it was marginal at best; but as a low grade producer, it had "ore to burn" and the potential for long-term dividends for the investors.[32] Continued examination of the property led to a working assumption that the copper deposit the syndicate had acquired was not a lode mine in the generally accepted sense of veins containing high grade ores; rather it was a huge mineralized area with a least two distinct ore zones.[33] The decision to equip and mine Britannia as a low-grade producer

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[32] George H. Robinson, "Analysis of the Reports of Neill and Allen as Compared with Statement on Howe Sound Copper Mine," October 29, 1901, PABC, Add. Mss. 1221, 127/3, p. 8.

[33] Kendall to Sawyer, October 14, 1903, PABC, Add. Mss. 1221, 127/5.

was formally made on September 2, 1903 when the shareholders voted to commit an initial $35,000 with Robinson as managing director. Work actually commenced on the 15th when 40 men were landed at the Beach site and began clearing land.[34]

The problems associated with the mining and treatment of low grade ores were being given considerable attention in Australia, Canada, and the United States at the turn of the century. In well defined ore bodies large scale mining methods were being developed which reduced or eliminated the need for timbering. A wide range of proposals were also available for treatment processes ranging from new methods of smelting to more intensive methods of gravity concentration which was the solution generally adopted.[35] A few of these proposals were adopted by Robinson in the mining system he designed for Britannia; but, in the main, his design reflected the schemes put forward by the earlier promoters of the property in its main outlines: square-set timbering where required and as much quarrying as possible; an aerial tramway to connect the mine and the mill; gravity concentration of the low grade ores; and smelter to be operated by the syndicate. While these four component subsystems generally defined the organization of the mine, the specific ways in which their details were planned, implemented, and integrated set limits on the overall capacity of the mine, its efficiency, flexibility, and profitability. The details of the plan and the expectations placed upon it also determined the numbers employed in the various component subsystems and the level of skill required of the workmen.

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[34] *Province,* September 2, 1903, p. 1; September 15, 1903, p. 1.

[35] Walter R. Crane, *Ore Mining Methods* (New York: John Wiley & Sons, 1910), pp. 95 - 155; Edwards Dyer Peters, "Treatment of Low-Grade Copper Ores," *Mining Record* 10, 7 (July 1903): 715 - 718; and Thomas B. Chapman, *Concentration of Copper Ores in North America,* U. S. Bureau of Mines, Bulletin No. 392 (Washington, D. C.: USGPO, 1936), pp. 1 - 2.

Initially, large numbers of construction workers were employed on the property and little, if any, work was done underground. A right-of-way was cleared for the tramway and a contract was awarded to the Riblet Company of Spokane, Washington for its erection. As designed, this vital link between the mine and the concentrator had a capacity of 100 tons per hour or 1,000 ton in a ten hour work day. This rate of movement plus the capacity of the ore storage bins at the mine and the Beach set outside limits on the amount of ore that could be in transit at any one time.[36]

While the design and erection of the tramway was delegated to an acknowledged specialist in the field, Robinson chose to rely on his own experience to plan the concentrator. A plant with a daily capacity of 500 tons was proposed since he expected much of the tramway's 1,000 tons per day would be devoted to moving direct smelting ores which would bypass the concentrator entirely. The assumption that the mine had "ore to burn" was also evident in the mill design. High losses of copper during the concentration process were considered acceptable as long as operating costs were kept low. "in other words," wrote Robinson, "I do not care to pay 95 [cents] for a dollar when I can get it for 65 [cents]."[37] The concentrating equipment, as it was initially designed, consisted entirely of horizontal gravity machines -- 38 Frue vanners and 30 Wilfley tables -- to treat a uniformly fine crushed ore, or pulp. After an initial crushing, the ore passed over a hand sorting belt where any remaining high grade ore was removed. The remainder was then ground and fed to the individual concentrators. Since each machine was treated as a separate unit producing a finished product, a large labour force was considered a necessity for the mill.[38] Given

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[36] *Province*, January 28, 1904, p. 1; April 9, 1904, p. 1; and June 28, 1904, p. 1.

[37] Analysis of the Reports of Neill and Allen, *op. cit.*, p. 8.

[38] For details on fine-sand concentration practice see Theodore Simons, *Ore Dressing Principles and Practice* (New York: McGraw-Hill, 1924), pp. 163 - 181. Simons discusses the techniques as outdated at the time of his writing.

that the nature of the ore body was still poorly understood, Robinson freely admitted that his best plans for the mill could be easily frustrated as more information was gained about the ore.[39] He explained his apparently casual approach to the mill's design in an interview with the Victoria *Daily Colonist*: "Other details of the work ahead will be worked out when the plans for the whole scheme are being prepared." In the meantime, the purchase of equipment and construction of the mill building went ahead.[40]

The final treatment of the ore before it left the syndicate's control was to take place either at a smelter to be erected at the Beach near the concentrator or at the Crofton smelter on Vancouver Island. The Crofton plant had been built by the Northwestern Smelting and Refining Company in 1901-02 to treat ores from the Lenore mine on Mount Sicker and presented an acceptable alternative to the construction of a new smelter in the region. In 1905 the Britannia syndicate purchased the Crofton plant and re-equipped it to handle approximately 500 tons per day through a second company, the Britannia Smelting Company. Not all the ore treated at Crofton would come from the Britannia mines as fluxing ores were required. To that end the syndicate arranged to lease the Mount St. Andrews mine on Prince of Wales Island, Alaska, and contracted for other ores from the Portland Canal area.[41]

The tramway, the concentrator, and the smelter existed to serve the output of the mine and their combined effectiveness was determined by the rate and quality of

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[39] *Province*, April 9, 1904, p. 1; August 11, 1904, p. 3; and September 12, 1904, p. 6.

[40] *Colonist*, August 20, 1903, p. 8.

[41] E. Jacobs, "Britannia Smelting Co.'s Smelting Works at Crofton, Vancouver Island, B. C.," *Mining Record* 12, 10 (October 1905): 371 - 376; *Mining Record* 11, 5 (May 1904): 172 - 173; 13, 3 (March 1906): 126; 13, 10 (October 1906): 379; BCDOM, *Annual Report, 1905*, p. 26; *Province*, April 1, 1905, p. 1; and April 4, 1905, p. 1.

production at the mine. Curiously, while considerable attention was given to the three dependent elements in the total system, little underground work of any kind took place while the rest of the physical plant was under construction. The mining methods selected for use effectively precluded any extensive underground work until the remainder of the system was completed and operating. The low grade Bluff mine would be developed for glory holing, a mining method which used raises driven up through the ore body to the surface from an underground haulage level. Once the raises were completed, the ore would be worked from the top down as a cone shaped pit was blasted out around the raise through which the ore fell to the lower level for transportation out of the mine. The raise would quickly fill with ore unless it was regularly drawn off from below; so, there was little reason to proceed with development and mining until the ore could either be stored outside the mine or moved down the mountain. A similar situation existed in the high grade Jane mine. Robinson hoped to open up this area with glory holes, also, since they provided the lowest-cost means of breaking and transporting ore within the mine. There was some doubt as to the safety of the method in the Jane mine due to structural weaknesses in the rock which increased the possibility of cave-ins and raised the danger associated with the work. Falling ground also diluted the grade of the ore produced and increased the amount of sorting required. Open stopes, another common method of mining copper in strong ground, were probably not considered for the same reason that the glory hole method was suspect. Consequently, plans were made to use the square-set method and logging and saw mill operations were organized. Advance production was also limited with square-sets. As the ore was mined and the timber sets installed, waste rock was sorted from the ore and used to fill the voids between the timbers to provide additional ground support and eliminate the need to transport waste out of the mine. Thus, there was little room for the large scale storage of broken ore underground. The mountainous terrain and the size of the storage bins

meant there was only a limited capacity on the surface.[42]

Given the restraints placed on underground work by these methods, preparations for production in the Jane Basin were limited to the construction of the surface plant and the installation of machinery. Because of heavy snow falls in the Coast Range covered trestles were built to connect the mine adits with a central crusher. After crushing the ore was passed over a belt where it was hand sorted for a second time to remove high grade ores from the concentrating grades. It was then emptied into a storage bin which served as the feed for the tramway. Electrical power to operate the crusher and an air compressor for the drills was supplied by a water powered generator installed at the Beach.[43]

While minor shipments of hand sorted ore had been sent to Crofton in 1904, construction was not completed to a level that would support regular operations until July 14, 1905. On that date the crusher in Jane Basin was turned on and ore began to pass through the system even though the concentrator was not completed. Start-up was based on the production of high grade, direct smelting ores which could be shipped immediately to Crofton and begin earning a return on the syndicate's investment.[44] Once actual mining commenced and ore began to pass through the system, "start-up" problems became evident and numerous modifications were necessary

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[42] Wm. M. Brewer, "Britannia Mines, Howe Sound, B. C.," *Mining and Scientific Press* 89, 25 (December 17, 1904): 408 - 409; BCDOM, *Annual Report, 1904*, p. 261; *Colonist*, November 27, 1904, p. 9; McClelland, *op. cit.*, see Section 10, pp. 530 - 555, especially pp. 536 - 538, on square-sets and pp. 697 - 699 on glory hole methods; and see Leong, *et. al.*, *Technology, Employment, and Output Per Man in Copper Mining*, National Research Council on Reemployment Opportunities and Recent Changes in Industrial Techniques, Report No. E - 12 (Philadelphia: Works Progress Administration, February 1940), "Table A-2. - Production of Copper Ore and Copper, By Mining Method, 1880 - 1936," pp. 216 - 217.

[43] BCDOM, *Annual Report, 1904*, pp. 264 - 265; and *Province*, July 15, 1905, p. 1.

[44] *Province*, June 7, 1905, p. 1; and July 15, 1905, p. 1.

to keep the mine operating.[45]

Between fifty and sixty men were employed underground in the Jane and Bluff mines when production mining commenced. The size of the work-force that could be constructively used was dependent on the physical size of the workings, specifically the number of work-places available. Since mining in the Bluff was restricted at first to driving the haulage level beneath the proposed glory holes, the initial crew size was small, probably no more than nine men divided between three 8 hour shifts. Once the tunnel was advanced past the raise stations additional crews could be employed. The majority of the men worked in the more extensive Jane mine where the decision had been made to use square-set timbered stopes. One source indicated that the initial Jane production was approximately 200 tons of ore per day or 4 tons per man shift based on a fifty man crew.[46] A second source suggested that a crew of seventy to eighty was involved in producing the same amount at start up which would mean a production figure of 2.5 tons per man shift which was still well above the North American average for square-set mining.[47] As the development drifts were extended and new stoping areas became available, more men were added with the expectation that production would quickly reach 500 tons per day. At 4 tons per man shift the requisite underground workforce would have been about 125; at 2.5 tons per man shift

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[45] As an aid to reading the next section it would be useful to see Appendix B and compare Figure 1, Proposed Flow Sheet of Britannia Ores, November 1904 to Figure 2, Operating Flow Sheet of Britannia Ores, August 1905 to February 1906.

[46] This production per man shift figure is suspect since in 1917 the average production of copper ores by square-set methods for all U. S. mines was 1.28 tons per man shift. Leong, *et. al., op. cit.*, p. 225. The Britannia employment figures probably do not take into account supervisory staff, mechanics, crusher operators, and other support workers employed at the mine end of the operation. Inclusion of this unknown number would lower the output per man considerably.

[47] E. Jacobs, "Britannia Copper Syndicate's Mines and Concentrating Works at Howe Sound, B. C.," *Mining Record* 12, 11 (November 1905): 422 - 423.

200 men would have been required.[48]

The production cycle -- drilling, blasting, mucking, tramming, timbering, and the advance of services -- was organized around the number of drills and drillers employed; the work of all others in the mine was controlled by the drillers' rate of advance. The number of drills was, in turn, dependent on the capacity of the air compressors. The first compressor on the property could not suppport enough drills to produce more than 300 tons per day. Two new compressors were installed in December 1905, and drills and manpower were increased to levels capable of producing 550 tons per day.[49] Critical as the ratio of manpower to production was at the mine, Robinson did not find it necessary to make any detailed estimates of employment expectations even after the mine had been in operation for two months. As he stated in a report to his financial backers in New York: "I do not know of course how many men it will require to break ore in that mine [the Jane], but do not think we will employ all told there more than 75 or 80 men."[50]

As the size of the work-force and production increased, new information about the ore body was obtained as a direct result of the advancing method of mining which combined production with exploration. Even more men were hired when the extension of the Jane workings surpassed the syndicate's hopes and exposed significant quantities of gold and high grade copper. All production continued to come from the labour-intensive Jane mine until June 1906 when the Bluff glory holes were completed.

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[48] These figures are rough estimates only as no detailed employment figures for 1905-06 have been uncovered beyond the two sources mentioned.

[49] *Province*, August 4, 1904, p. 2; August 26, 1905, p. 16; December 2, 1905, p. 5; March 13, 1906, p. 1; and *Colonist*, August 9, 1904, p. 3.

[50] G. H. Robinson to Henry Stern, September 3, 1905, PABC, Add. Mss. 1221, 114/9, p. 27 - 28.

The ores in the second mine soon proved to be of direct shipping grades also. Since these ores did not need to be concentrated as originally planned, that section of the system was by-passed, more men were put on, and production rose quickly to around 700 to 800 tons per day. The direct relationship between production and manpower was demonstrated in a newspaper report stating Britannia would increase its output even further if only more miners could be found. Finally, in September 1906, a second vein was intersected in the Bluff zone which averaged 6 to 7% copper and Britannia began to question its definition as a low grade producer.[51]

The steady increase in the underground work-force finally ended in November 1906 when the limits of the mechanical support system were exceeded. The layoffs that followed demonstrated the relationship between production levels, employment, and the efficient use of equipment. At first, Britannia spokesmen explained the reduction in production levels was because the Crofton smelter could not handle the mines' rapidly increasing output which was undoubtedly true. One week later a more detailed explanation was given; the blame was placed on declining productivity and insufficient air pressure. As men were added, machine drills were added; but for some weeks prior to the layoffs, output had not increased in direct proportion to the manpower levels. The indiscriminate addition of drills had resulted in a situation where fifteen drills were being supplied with air from a compressor that was only adequate for ten. Forty-eight men were let go immediately and more followed as five drills were taken out of the mine. While only fifteen drillers (five on each shift) were directly affected, the remainder of the layoffs consisted of the drillers' helpers, muckers, ore sorters, trammers, and timbermen who were dependent on the operation of the drills for continued employment. Just as little consideration was given to the nature of the ore

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[51] *Province*, February 21, 1906, p. 7; March 13, 1906, p. 1; March 21, 1906, p. 1; June 4, 1906, p. 1; June 21, 1906, p. 13; September 15, 1906, p. 1; and *Colonist*, June 20, 1906, p. 1.

body before mining commenced, even less was taken of manpower and equipment requirements and the balance between them necessary to operate the mine at various production levels.[52]

The sorting of waste rock from the ore was a labour-intensive, multi-stage process which began in the timbered stopes where rock carrying values of 1% copper and less was used to fill the voids left by mining. The ore was then hand trammed out of the mine and crushed to a size suitable for transportation on the aerial tramway. After crushing, it was passed over a sorting belt where additional waste rock and any ore identifiable as 4% or better were removed by hand. The sorting was done by Japanese labourers who were required to quickly recognize the difference between waste and at least two grades of ore. Finally, the ore was deposited in 3,000 ton capacity storage bins in preparation for tramming.[53]

Once the ore left the mines, the capacity of the tramway presented another restraint on the overall production of the mines. The Riblet Patent Automatic Aerial Tramway was constructed in two sections for a total length of 16,800 feet. Ore was automatically loaded at the upper terminal in the Jane Basin and carried to an intermediate station where it was discharged into another 3,000 ton capacity storage bin from which it was reloaded onto the second leg of the tramway. The capacity of this system as built was 50 tons per hour or 500 tons per 10 hour day in November 1905. This was one half the original design capacity, a situation resulting from the installation of only half the specified number of buckets. The towers and cables, as installed, were sufficient to handle the full 1000 ton per day load. As mine production increased the limits of the tram were soon exceeded and additional buckets were

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[52] *Province*, November 28, 1906, p. 1; and December 7, 1906, p. 1.

[53] G. H. Robinson to Henry Stern, *op. cit.*, p. 4; BCDOM, *Annual Report, 1904*, p. 265; and *Colonist*, November 7, 1904, p. 9.

installed. By the summer of 1906, consideration was given to erecting a second tramway to handle the daily production of 700 to 800 tons. The storage bins at the top and intermediate which had been intended to provide some flexibility for the system were constantly full. While aerial tramways provided a solution to bulk transportation in mountainous terrain, it was difficult to increase their capacities beyond the limits established at the time of construction which made there use an effective bottleneck to expansion. They were also expensive to erect and operate; labour costs constituted the single largest cost of transporting ores by this method. Even with automatic loading and unloading devices, at least two labourers were required at each station to act as breakmen as well as a full time oiler and foreman. Maintenance costs were also high as skilled labour was required to effect frequent repairs due to damage caused by overloading the system. The unexpected emphasis on direct shipping ores added an additional 35,000 tons to the 55,000 tons of concentrating ores that were carried in 1906.[54]

Once the ore arrived at the Beach it was either shipped directly to Crofton or stockpiled for eventual concentration. The mill consisted of two major buildings: the crushing plant and the concentrating building. Due to the lower costs and higher returns derived from shipping high grade ores the concentrator was not placed into full operation until December 1905. Other than the addition of one Australian (Hancock) Jig, the mill was constructed to handle a uniformly finely ground ore as originally designed. The fine grinding was the result of the unquestioned assumption that the mines would be essentially low grade. Once the mill was placed in operation,

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[54] Jacobs, *op. cit.*, pp. 423 - 424; Edward R. Durham, "Aerial Tramways and Cableways," in Peele, 1st ed., *op. cit.*, p. 1588; O. H. Metzger, "Aerial Tramways in the Metal Mining Industry: Part 2. Construction and Operating Costs," U. S. Bureau of Mines, Information Circular No. 7095, February 1940, pp. 22 - 24; BCDOM, *Annual Report, 1904*, p. 265; *1906*, p. 26; *Province*, August 14, 1906, p. 13; and November 12, 1906, p. 1.

the Hancock Jig proved to be the one piece of equipment which performed according to expectations since it was designed to capture the higher values. Thus, from the very beginning the concentrating plant was mismatched with the ore body and less than efficient.[55]

Despite a large number of machines, the concentrating plant was labour-intensive throughout as Robinson had anticipated. As the ore passed from the crusher on a conveyor, Japanese sorters once again removed high grade ore and waste. The sixty-nine machines required an average of one operator for every two machines as well as maintenance staff and bull gangs to move ore and supplies about the mill. While Robinson claimed that he had less difficulty in starting up the Britannia mill due to an extensive series of trial operations, it is his approach to labour management, not metallurgy, that is enlightening:

> Another difficulty we have had to contend with is that of labor. I concluded that the better way to start the plant was to educate the people whom we have here, who would like to make this their home and permanent residence. We know them. They are reliable, proficient in the line of work at which they have been employed, but unfortunately for us in the start were not mill men. While I know if I sent away for mill men that the assumption would immediately go out that we were depending on other people for our skill. Instead therefore of sending out I have run the works slowly and taught the men we have here to operate them. This has been a slow and troublesome proceeding but had I sent for men it would have simply resulted in inauguarating immediately a complete labor union organization. As it is one man has put in an appearance on the job who has now been dispensed with for this peculiarity. It is not my purpose to have friction of this kind at the Beach.[56]

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[55] Robinson to Stern, *op. cit.*, p. 10; BCDOM, *Annual Report, 1906*, p. 26; *Mining Record*, 13, 1 (January 1906): 31 - 33; *Province*, August 25, 1905, p. 1.; and *Colonist*, August 29, 1905, p. 2.
[56] Robinson to Stern, *op. cit.*, pp. 14 - 15.

Thus, while Robinson was willing to concede to the skills of the miner, he was not willing to do so in the mill where the skills required to run the concentrator were in his possession.

During the first full year of operation the inadequacies of the concentrator design were fully demonstrated despite a reliable work-force. After Robinson's death in 1906, Mason T. Adams assumed the position of managing director and shut down the plant and attempted to re-design it in line with the metallurgical characteristics of the ore being mined. The new system of concentration involved a change from fine to coarse crushing and grinding. The ore was then classified and fed to the appropriate machines based on its particle size. The waste products from these operations would then be further ground and reprocessed. Labour requirements remained high since the basic design of the plant as a series of independent machines had only been partially modified.[57]

In a 1908 letter to the shareholders, R. H. Leach, who succeeded Adams as general manager, explained the failure of the first mill design in terms that could have been generally applied to the entire mining system as first implemented: "The failure of the mill was due to the lack of development work in the beginning, which would show up the exact character of the ore to be treated, and the original plant erected was not adapted to the work required. The losses of copper in this mill have been enormous."[58] The recovery rate of the initial mill design was not stated; but even with the elaborate reorganization of the machinery to handle a variety of ore

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[57] Canada, Department of Mines, Mines Branch, *Report on the Mining and Metallurgical Industries of Canada, 1907-8* (Ottawa: Gov't Printing Bureau, 1908), pp. 144 - 145; and BCDOM, *Annual Report, 1907*, pp. 158. See Appendix B, Figure 3, Flow Sheet - No. 1 Britannia Mill, 1907-08.

[58] "To the Stockholders of the Britannia Copper Syndicate, Limited," February 17, 1908, BCMM-CF, Discovery File No. 2.

sizes, the copper saved by the process amounted to between 75 and 78% of the estimated contents of the ore.[59]

After Robinson's death in 1906, the Britannia mines continued to operate on a marginal basis for a period of approximately five years during which a succession of managers attempted to modify the mining and milling systems to the point where they could produce a profit. During the same period of time, the corporate structure of the enterprise was reorganized to reflect the increasing financial control exercised by Moore and Schley who continued to advance funds to the mine. In 1908, the Britannia Copper Syndicate Limited and the Britannia Smelting Company were restructured as subordinate units of the newly formed Britannia Mining and Smelting Company. Controlling interest in this British Columbia corporation was held by Schley's Howe Sound Company of New York.[60]

Britannia's efforts to perform as a high-grade producer were short-lived since the high-value copper ores were not uniformly distributed in the ore body and were primarily confined to the initially exploited oxidized zone near the surface.[61] Managing Director Mason's reorganization of the concentrator reflected the realization that the mine was, indeed, a low-grade producer and that its continued operation was not ensured under the original production scheme. By 1919, all ores from the mines were being concentrated. Mason also upgraded the mines' compressor capacity to ensure

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[59] S. S. Raymond, M. E., "Report on the Empress Mines, British Columbia," December 1909, PABC, Add. Mss. 1221, 114/11, p. 6.

[60] James, *op. cit.*, p. 71; and BCDOM, *Annual Report, 1915*, pp. 295 - 296.

[61] For a general description of the state of geological knowledge at Britannia at the time, see Canada, Department of Mines, *Summary Report of the Geological Survey, 1913* (Ottawa: King's Printer, 1914), pp. 77 - 78. The exploitation of oxidized ores was characteristic of nineteenth century metal mining in general and often gave rise to unrealistic expectations as to the potential of an orebody. See E. D. Gardner, C. H. Johnson and B. S. Butler, *Copper Mining in North America*, U. S., Bureau of Mines Bulletin No. 405 (Washington, D. C.: USGPO, 1938), pp. 48 - 50.

stable production and forestall any repetition of the previous layoffs for mechanical reasons. More importantly, he initiated a diamond drilling programme on the property in an effort to define new ore bodies and reduce the element of chance associated with the advancing method of mining.[62]

Robert H. Leach, the first general manager appointed after the 1908 reorganization, presided over the termination of operations at the high-cost Crofton smelter and arranged for all concentrates to go south to the Tacoma Smelting Company while the Crofton plant was dismantled. Leach continued the underground and surface diamond drilling programmes begun by Mason and concentrated on defining a new ore body on the Fairview claim to the east of the Bluff mine. The results were inconclusive since Leach was unwilling to place any excessive amount of faith in the information garnered from the drill cores. His more immediate concern was developing a method to separate the copper ore from the zinc that was beginning to appear in the Bluff ores. The presence of zinc created serious difficulties at the smelter and ores contaminated with the metal were heavily penalized by all custom

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[62] BCDOM, *Annual Report, 1907*, p. 158. Production figures (in tons) for the first seven years of operation reflect the rapid rise and subsequent decline of the importance of direct smelting (D. Smlt.) ores.

Year	Mined	Milled	D. Smlt.	% D. Smlt.
1905	17,082	13,000	4,082	23.8
1906	88,879	53,492	35,387	39.8
1907	57,374	26,730	30,644	53.4
1908	17,624	10,450	7,174	40.7
1909	17,226	17,226	0	0.0
1910	26,837	26,837	0	0.0
1911	118,908	106,904	?	?

Production figures for 1911 reflect increased investment in the mines and a change in mining systems which make it difficult to calculate the percentage of direct smelting ores from the source used since not all ores mined were milled or even removed from the mine in the same year. Table derived from BCDOM and Bureau of Economics and Statistics, Victoria, B. C., Gross Contents: Britannia (updated annually), BCMM-CF, History Reviews File (See Appendix D).

smelters. A small zinc concentrating plant was erected in 1910 on the basis of laboratory tests conducted in Denver, but it was never completed since other experiments with the Elmore flotation process were begun the next year.[63] Leach was a cautious innovator as demonstrated by his assessment of the plans for the zinc concentrator and the experiments with the Elmore process: "These tests are very satisfactory, but of course, being laboratory tests can only be taken as indicative of what possibly might be obtained in actual practice."[64]

The overall performance of the Britannia mines during the 1906 - 1910 interregnum was assessed in 1911 by Wm. Fleet Robertson, the Provincial Mineralogist. He reported that even though an underground work force of 145 men was able to sustain production at 500 tons per day, the grade produced was too low to earn a profit for the company in the depressed copper market of 1908 - 1911. The high-grade bonanzas were not even a memory for Robertson. The ores he saw were so low in copper and the concentration process so inefficient that the mine could "not make a concentrate running even 7 to 8 per cent. copper; consequently, these old ore bodies would not allow a profit with copper at [the low price of] 12 cents a pound."[65]

By 1911 the Howe Sound Company had made a decision to revitalize the Britannia property on the basis of several years of investigation into ways to reorganize the existing mining and milling systems. A 1910 engineering report had suggested that the mine, as it was then organized, would never make a profit when the price of

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[63] BCDOM, *Annual Report, 1911*, p. 202; Archibald to Leach, December 31, 1909, Henry Patten Archibald Papers, Vancouver City Archives, Add. Mss. 256, 32/3; Report of R. H. Leach, March 7, 1910, PABC, Add. Mss. 1221, 114/30; and T. A. Rickard, "The Britannia Mine and Mill," *Mining and Scientific Press* (November 11, 1916): 694.

[64] Report of R. H. Leach, March 6, 1911, PABC, Add. Mss. 1221, 114/30.

[65] BCDOM, *Annual Report, 1911*, p. 202.

copper was even moderately depressed. The question of building a new smelter at the Beach was raised one last time and then abandoned in favour of concentrating on improved mining and milling methods. The universal usage of square-set timbers at Britannia was questioned, and it was suggested that in narrower veins waste rock alone would suffice for ground support. While such a change in mining technique would reduce costs somewhat and displace some timbermen, it would not significantly alter the basic labour-intensive mining cycle. The final suggestion for the mine noted the ready availability of electrical power and recommended that the mules used for underground haulage be replaced by electric locomotives on long hauls. Short trams should continue to be done by hand. Recommendations for milling operations stressed that the basic process was sound, but needed attention to detail. An extension of hand sorting to exclude up to 25% of the mill feed as low-grade waste was expected to raise the final copper recovery to as much as 80%. Ores that did not concentrate well, such as those from the zinc laced Bluff mine, should be hand sorted and shipped directly to the smelter without wasting funds on ineffective milling efforts. In short, the mill should be made even more of a hand labour process.[66]

The 1910 report had stressed that the management of the mines was "intelligent, efficient, and economical." Nevertheless, on November 17, 1911 Leach was replaced by John Wedderburn Dunbar Moodie as general manager. As befitted his close connection to Grant Schley, Moodie was also appointed vice-president of the Britannia company and given a wide ranging authority to revive the mine. Moodie was a native of Hamilton, Ontario, but he had gained much of his experience in mining at the Tintic mine in Utah before being brought to Britannia. While little is known of his background, his influence on Britannia was considerable since he directed the

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[66] Louis S. Noble to Grant B. Schley, August 2, 1910, PABC, Add. Mss. 1221, 114/14.

first major reorganization of mining practice on the property.[67] When Moodie arrived, attrition had reduced the mine's staff to a minimum; Moodie proceeded to rebuild the office and technical staff with his own appointees and introduce a "general business system into every branch of the Britannia affairs," which one observer described as "the most important and most needed change which has come in with the new management."[68] The object of the reorganization was to increase the scale of operations and improve and control the facilities in the various departments so as to "result in cheaper costs, larger tonnage, and the ability to work lower grade material not now included in ore reserve figures." The goal was to give "elasticity to the operation and [make] it possible to control grade of production and increase tonnage at any time."[69] Elasticity was achieved by expanding the capacity and efficiency of mining and transportation systems so that significant amounts of ore could be stored in the mine and by adopting milling techniques that allowed the use of the extensive low-grade ores in the mines.

Major changes were introduced underground almost immediately. Timbered stopes were totally abandoned in favour of the shrinkage method in the Jane mine and the newly opened Fairview mine.[70] Since no timbering was to be used for ground support, the broken ore would be used to stabilize the walls of the stopes and form a working floor for the miners. Only enough ore would be removed from a stope at any one time to allow sufficient headroom to work. The broken rock would no longer

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[67] *Ibid.*, p. 13; Ramsey, *op. cit.*, 56, 83; and BCDOM, *Annual Report, 1912*, p. 201.

[68] Noble to Schley, January 12, 1912, PABC, Add. Mss. 1221, 114/19, p. 8.

[69] Noble to Schley, April 26, 1912, PABC, Add. Mss. 1221, 114/20, pp. 2, 6.

[70] For a detailed description of shrinkage stoping as practiced at Britannia, see C. O. Swanson, "Stoping Practice at Britannia Mines, B. C.," *Transactions of the Canadian Institute of Mining and Metallurgy* [hereafter Trans. C. I. M.] 24 (1921): 225 - 231; and C. P. Browning, "General Mining and Milling Practice at the Britannia Mine, Howe Sound, B. C.," *Trans. C. I. M.* 25 (1922): 201 - 204.

be sorted into waste and ore in the stopes, nor was there a need for many muckers to move the ore around and into chutes as had been the case with square-sets. Furthermore, the ore could be stored in the stopes for extended periods of time before in was drawn. Shrinkage stoping meant that daily mine production no longer determined the immediate supply of ore for processing in the mill. This change also allowed Moodie to increase the size of the work-force involved directly with production while reducing the numbers associated with any one work-place within the mine. Besides the virtual elimination of timbermen, work in the stopes no longer involved considerable amounts of shoveling or sorting since the entire mass of broken ore was drawn off from below by the tram crews. In the first year of use, ore production was almost doubled. While the production cycle was still dependent on the driller for its rate of advance, the cycle had been reduced in its complexity and individual productivity increased due to the elimination of some tasks in the cycle.[71]

Skill levels, in so far as the ability to recognize ore from waste *in situ* was an integral part of the advancing method of mining, were reduced by the increased use of diamond drilling as an underground exploratory tool. Limited use of the drills enabled the mining engineers to determine the ore qualities of a given area of the mine before tunneling into it. The drill hole could then serve as a base line for the miners to follow in tunneling operations. More extensive use of the drills enabled the management to determine the value, shape, and grade of a given ore body and determine appropriate means of approaching and mining before commencing operations

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[71] The increase in productivity was difficult to measure in terms of tons per man day since the broken ore was not immediately drawn from the stopes. L. S. Noble to G. B. Schley, January 12, 1912, PABC, Add. Mss. 1221, 114/19, p. 5; BCDOM, *Annual Report, 1912*, p. 201; Crane, *op. cit.*, p. 27; McClelland, *op. cit.*, pp. 585 - 598, esp. pp. 597 - 598; Chas. F. Jackson, *Shrinkage Stoping*, U. S., Bureau of Mines, Information Circular No. 6293, June 1930, pp. 6 - 7; and Chas. F. Jackson and E. D. Gardner, *Stoping Methods and Costs*, U. S., Bureau of Mines, Bulletin No. 390 (Washington, D. C.: USGPO, 1936), pp. 132 - 137.

instead of proceeding blindly into the earth or relying on information obtained as a secondary result of active mining. By 1919, diamond drilling in new ground had become a common practice in the working of the Fairview mine and the development of the Empress and Victoria mines.[72]

The use of diamond drilling during the teens should not be construed as a total revolution in underground exploration. The use of the tool was casual when compared to more recent applications; the ore bodies were still primarily developed by drifts and cross-cuts with the diamond drill being used to check the end and width of a given vein.[73] Even so, the use of the drills at Britannia. as practiced in 1912, assisted the mine staff in reevaluating its method of calculating ore reserves in terms of geology, metallurgy, and structure.[74] The definition of reserves -- information increasingly important to the planning of operations -- was proceeding at a rate of 2.5 tons of ore blocked to every ton of ore drawn from the stopes. On the basis of calculated reserves, preparations for mining otherwise known as development work was advancing at a rate equal to 1.5 tons developed to every ton drawn. The miner, skilled or not, had little to do with this development.[75]

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[72] Engineer's Report to J. W. D. Moodie, January 1, 1920, PABC, Add. Mss. 1221, 1/5, pp. 1, 57, 62.

[73] Interview with Donald C. McKechnie conducted by Susan Green and Marilyn Mullan, January 29, 1985, item 17.

[74] The determination of acceptable grades of ore was set by the milling process and market conditions and was only peripherally related to the information obtained through diamond drilling and other methods of exploration.

[75] Agreement between Britannia Mining & Smelting Co. and Diamond Drilling Contracting Co., May 16, 1911, PABC, Add. Mss. 1221, 117/12; L. S. Noble to G. B. Schley, April 26, 1912, PABC, Add. Mss. 1221, 114/20; and Mine Superintendent and Mine Engineer to J. W. D. Moodie, January 1, 1913, PABC, Add. Mss. 1221, 1/1, p. 1. For a discussion of the uses of diamond drilling prior to 1915, see McClelland, *op. cit.*, pp. 415 - 418, 420.

Although the adaptation of shrinkage stoping to the Britannia ores was the major change in mining methods introduced while Moodie was general manager, there were other innovations during the nineteen-teens which indicated a increasing degree of sophistication in the selection and use of mining methods.[76] As the average acceptable grade of ore was lowered, plans were initiated to draw off the waste filling or "gob" in the old square-set stopes of the Jane mine. The previously defined waste had averaged 1% copper. When this ore was included in the calculations of overall reserves it did not dilute the general mine run below the 2% cut-off point. The timbered areas would simply be treated as a shrinkage stope and the ore drawn off through chutes opened at the bottom of the old workings. The ore was then obtained at minimal expense since the rock had been broken years before.[77]

Under the new system of mining the underground work-force directly involved in breaking ore was divided into four major groups. The first consisted of one or two dozen "all-round" miners and their helpers who worked in the higher grade ores and on development work. This group was paid more and was allowed a certain degree of latitude in the way they drilled and blasted so that they could use their skills to take advantage of their knowledge of the rock. The second group was comprised of the vast majority of drillers (stopers) who worked in the production stopes at locations assigned by the foremen. These men drilled verticle holes in predetermined patterns. The third group consisted of "a specially trained crew of blasters who made the most

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[76] It should be born in mind that a mining method involves an overall approach to the removal of ore and is not tied specifically to mechanical appliances; therefore, the degree of mechanization of a method is not necessarily the primary determinant of its use. Jackson and Gardner, *op. cit.*, pp. 26 - 40.

[77] W. A. Wyllie and C. E. Copeland to J. W. Moodie, Janaury 1, 1915, PABC, Add. Mss. 1221, 1/2, p. 20. The practicality of the recovery of low-grade wastes from previous operations was based on changes to the milling technology to be discussed below; in short, it resulted from the observation that the lower the grade of ore fed to the flotation machines in use in 1915 - 1916, the higher the rate of recovery. Rickard, *op. cit.*, p. 696.

economical use of the different grades of explosives."[78]

The fourth group consisted of the seasonally employed glory hole miners. When Moodie assumed responsibility for the mine, the Bluff glory holes were taken out of production due to the problems with zinc. The method was not used again until 1916 when the Violet Glory Hole Stope was opened in the Fairview mine. The practice of the method remained much the same except for the introduction of electrical blasting which reduced the time involved in the operation and limited the amount of fly-rock. The glory hole miners continued to do their own blasting.[79] While they did retain control over a greater range of tasks associated with their work than the average stope miner, their production was closely monitored as the mine engineer's description of the operation illustrates:

> The Glory Hole Raise broke through to surface at a point 66 ft. vertically above 150 Level and No. 97 Raise to Surface at a point 108 ft. above 150 Level. After the ground had been cleared and shallow overburden removed from around these raises Glory Hole mining was started the first of September. An average of 8.5 machine men and 7.1 muckers were employed per day up until the last of November when work was suspended due to the heavy fall of snow. During these three months 36,732 tons of 3.6% ore was broken and the two raises connected into a glory hole stope.[80]

In effect, calculations of worker productivity were being made possible through systematic record keeping and a more sophisticated knowledge of the ore body. In the case of the Violet Glory Hole, it was possible to determine that each miner's day

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[78] Browning, "Mining and Milling," *op. cit.*, pp. 202 - 204; and McKechnie Interview, *op. cit.*, item 20.

[79] BCDOM, *Annual Report, 1917*, p. 298; and Browning, "Mining and Milling," *op. cit.*, p. 204.

[80] A. H. Burroughs to J. W. D. Moodie, January 1, 1917, PABC, Add. Mss. 1221, 1/4, p. 14.

wage represented an average production of 26.16 tons of ore.

The transportation bottleneck also received detailed attention as an integral part of the reorganization. In the underground workings, the production stopes were arranged so that each level was connected with a large, centrally located ore chute which carried all the ore down to the lowest level of the Fairview mine. Ore collected from the stopes was hand trammed to a central ore pass in 1.25 ton cars and dumped. On the haulage level below the ore was drawn through a chute into 2.5 ton cars and made up into trains to be pulled by electric locomotives powered by overhead trolly wires. One such train operated in 1911 and a second was added in 1912 which resulted in a near doubling of tonnage delivered to the rock house in the Jane Basin. Each locomotive hauled five loaded cars out of the mine. In 1914 a third and larger locomotive was added which was capable of pulling eight loaded cars. The loading gates in the underground chutes which filled the trains and at the ore bins which fed the crushers were redesigned so as to practically eliminate all hand shoveling which reduced the rock house crew to one man per shift while speeding up the entire operation. In 1912, the first full year of operation, the tramming system handled a little over 193,000 tons of ore as compared to approximately 100,000 tons the year before. Thereafter, as production increased in the stopes and more ore was required to feed the mill, more locomotives and cars were added to handle the requisite tonnage. In 1916, four storage battery type motors were acquired which gave the entire system a greater degree of flexibility since they could service parts of the mines not equipped with the overhead trolly wires demanded by the first three electric motors.[81]

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[81] BCDOM, *Annual Report, 1911*, p. 213; *1912*, p. 201; Mine Superintendent and Mine Engineer to J. W. D. Moodie, January 1, 1913, PABC, Add. Mss. 1221, 1/1, p. 16, 18; W. A. Wyllie and C. E. Copeland to J. W. D. Moodie, January 1, 1915, PABC, Add. Mss. 1221, 1/2, p. 19; and Burroughs to J. W. D. Moodie, Janaury 1, 1917, PABC, Add. Mss. 1221, 1/4, p. 52.

Plans to eliminate the aerial tramway entirely were proposed in 1911 and construction began in 1912. A new adit was driven on the 2200 Level, well below the active mine workings and connected to them by a series of raises.[82] Ore brought out through this tunnel was transferred to a surface railway which wound its way around the mountain to a point within one mile of the Beach. Final transport to the mill was by means of an incline railway which covered the steepest part of the grade. This system was completed in 1915 in time to service the first units of the new mill under construction at a rate of 1,000 tons per day. The aerial tramway continued to operate and provide 800 tons per day to the old mill for a combined minimum of 1800 tons of ore per day delivered to the Beach.[83]

Further refinements to the transportation system involved moving towards an entirely underground route. This move received an added sense of urgency in March 1915 when a massive landslide in the Jane Basin burried the mine camp, the upper tramway terminal, the service buildings, and took 57 lives.[84] After the slide, major mine services and housing for the miners were relocated to a townsite built near the 2200 portal, well away from the Jane Basin. A second main haulage level, the 2700 level tunnel, was begun in 1917. It was designed to open up more ground for mining, maintain the gravity flow system within the mine, and supplement the surface railway as another link between the mine and the incline railway. Another even lower level, the 4100 haulway, was begun from the Beach at the back of the mill. It was initially designed to bypass the incline railway by way of a rock raise to the head of the

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[82] For level designations see Appendix A, Plan 1: Verticle Plan of Workings as of 1932.

[83] BCDOM, *Annual Report, 1911*, p. 203; *1913*, p. 302; *1914*, p. 390; *1915*, p. 294; and "The Britannia Mine and What it Means to Vancouver," *Industrial Progress and Commercial Record* 3, 1 (July 1915): 7.

[84] BCDOM, *Annual Report, 1915*, pp. 295 - 296.

surface railway and the mouth of the 2700 adit; secondly, it was to open up even more ground. Each haulage level was to be connected to the one above it by raises housing underground crushers which would reduce the number of operations taking place outside the confines of the mine.[85] The wider plans for the underground transportation system were even more grandiose than what was eventually built:

> My imagination does not stop at this point, for having put orebodies in place, I can see them being actively worked. Perhaps a sea-level tunnel will reach from its portal at the Beach east under Britannia Mountain to the Saulter claims, with branches or "feeders" to tap outlying districts, notably the Marmot-Tipping belt. Above it will be a network of raises and tunnels serving individual orebodies, while honeycombs of drifts, crosscuts, raises, and stopes, representing orebodies being worked out, will be scattered here and there all over our 11,000 acres. This sea-level tunnel will be as busy carrying ore as is the New York subway carrying human beings.[86]

The increased capacities of the mines and the transportation systems were essential features in supporting a milling method that was capable of handling large volumes of low grade ores in order to produce copper concentrate at a low unit cost. The initial experiments with the Elmore oil flotation process were deemed successful enough by the New York office that further investigations were made and in 1912 a fifty ton unit supplied by the Minerals Separation Company was attached to the existing mill to treat the tailings from the gravity concentrators. Thus, Britannia was the first British Columbia mine to install and operate flotation equipment as a part of their regular concentration practice.[87]

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[85] E. A. Haggen, "Board Trade Visits Britannia Mine," *Mining, Engineering and Electrical Record* 21, 4 (July & August 1916): 71 - 74; BCDOM, *Annual Report, 1917*, p. 274;
[86] W. L. Thomas to G. B. Schley, May 29, 1914, PABC, Add. Mss. 1221, 120/39, p. 2.

As a short term measure the practice was successful and both tonnage treated and copper recovered increased. The long term solution to treating the low grade ores was the construction of an entirely new mill with a much larger capacity than the 850 tons available in the first concentrator. The new mill was designed as a series of independent units with an eventual capacity of 2,000 tons per day. In 1915, construction had progressed to the point where 1,000 tons per day were being treated. The next year the entire mill was finished for a total capacity of 2,500 tons per day. Combined with the old mill, Britannia was able to process well over 3,000 tons of copper ore on any given day.[88]

While flotation greatly increased the ability to work low grade ore bodies, the process did not immediately replace other methods of concentration. Rather, flotation machines were installed along with table concentrators and jigs in varying configurations - - at first flotation was used as either an intial or a final treatment. At Britannia, the process was used to treat the tailings from the Overstrom tables and the Hancock jigs. Thus, concentrates were produced at three major points in the process: after hand picking, after mechanical separation but before flotation, and after flotation.[89]

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[87](cont'd)[87] As mentioned earlier, flotation had been attempted in British Columbia as early as 1902, but it had not been considered a commercial as opposed to a technical success. Considerable refinement of the process had occurred in the intervening years. Britannia adopted flotation for copper ores the same year the process was installed at the Braden mine in Chile which is generally considered to be the first copper mine of any importance to use the process. A. B. Parsons, *The Porphyry Coppers* (New York: AIMME, 1933), p. 154.

[88] BCDOM, *Annual Report, 1912*, pp. 113 - 114; *1913*, p. 302; *1915*, p. 294; *1916*, p. 371; "Gross Contents," *op. cit.*; and E. Jacobs, "Notes on the Copper Mining Industry of British Columbia," *Trans. C. I. M.* 16 (1913): 582.

[89] Parsons, *op. cit.*, p. 446. For the layout of the Britannia mill see Appendix B, Figure 4: Flow Sheet - No. 2 Britannia Mill, 1916. The relative proportions of the ore recovered at various stages in the No. 2 Mill gives some indication of the relative efficiency of gravity and flotation methods used in combination.

Method	**Proportion (%)**	**Cu Content (%)**
Picked ore	10	10 - 18

The mill was constructed in two stages and was composed of four independently operated units of 1,000 tons capacity. The arrangement allowed a high degree of flexibility in operating levels: each unit could process up to 1,000 tons daily and the separate units could be adjusted to treat metallurgically distinct ores simultaneously. Units could also be taken out of production for repairs at any time without curtailing the work in the adjacent units. The entire structure was erected on a steep hillside to take advantage of gravity to move the ore to each successively lower level in the mill and each subsequent treatment. Electricity was used throughout to power the various machines.[90]

The extensive reliance on gravity as a motive force throughout the mine and the mill meant that there was little manual labour involved in moving the ore through either system. Work in the No. 2 Mill at Britannia has been described by T. A. Rickard who visited the mine in 1916, the first year the complete mill was in operation. On August 27, the day of his visit, three of the four units were in operation at a rate of 1700 tons per day. A crew of 83 men was employed, 25 of whom were Japanese. After the initial crushing and classification into two sizes, the undersize was passed directly to a series of rollers which further reduced the particle size. The oversized ore was carried over two picking belts with two men working each belt. Silicious ores containing between 10% and 18% copper were removed and shipped separately to be used as fluxes at the Tacoma smelter. Identifiably hard pieces of waste rock were also removed for later use as an abrasive in a fine grinding process.

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[89](cont'd)

Jig concent.	25	16 - 17
Table concent.	25	14 - 15
Flotation	40	14 - 15

Source: Rickard, *op. cit.*, p. 695.

[90] BCDOM, *Annual Report, 1917*, p. 275, and "Verticle" and "Horizontal Plan of 1,000 Ton Unit of Britannia 4,000 Ton Mill," between pp. 272 and 273.

Thereafter, labour's role in the mill was to tend the various machines, shepherd the ore between them, and perform maintenance chores until the concentrates were delivered to storage bins to await shipment.[91] The critical selection and application of reagents and oils for the flotation process was done under prescribed methods in predetermined amounts provided by the metallurgical staff."[92]

On the day of Rickard's visit the mill and its crew processed an average of 20 tons per man shift. When the entire 4,000 ton capacity of the mill was utilized, crew requirements no longer increased proportionately; instead, the effect of increased unit capacities was a marked increase in tons treated per man shift and an overall reduction in labour requirements.[93] Even if the mill crew was increased to 125 men, each man would still account for 32 tons which is equivilent to the North American average for copper concentration by all methods during the 1930s. The actual figure at Britannia for the operation of the No. 2 Mill was probably somewhat lower since Rickard's manpower figures did not include support workers and supervisory staff usually included in such calculations.[94] Nevertheless, the net effect of the new mill was to reduce the overall significance of manpower in the concentrator and to shift the emphasis from skilled production workers to skilled tradesmen who repaired and maintained the plant. Furthermore, the changes in milling techniques began to alter the ratio of employment that had existed between the mining and milling components of the operation prior to the introduction of flotation and unitized mills. Whereas in 1911

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[91] Rickard, *op. cit.*, pp. 694 - 696; see also Browning, "Mining and Milling," *op. cit.*, p. 210.

[92] A. C. Munro, "Milling Practice at the Britannia Mines, Howe Sound, B. C.," *Bulletin of the Canadian Institute of Mines and Metallurgy* [hereafter Bulletin, C. I. M.] 140 (December 1923): 639 - 642.

[93] T. G. Chapman, *Trends in Practice and Costs of Concentrating Copper Ores*, U. S., Bureau of Mines, Information Circular 6792, September 1934, p. 18.

[94] Leong, *et. al., op. cit.*, p. 169.

an average of 180 men had been employed in the mill to process 850 tons daily and there were 145 in the mine to supply the ore, by 1916 as few as 83 millmen could produce 1700 tons. Mine productivity in terms of tons per man shift had also increased but not to the same degree. Once flotation was introduced as a regular process, the mill crew would never again outnumber the mine crew.[95]

The reduction in the size of the mill work-force was gradual and was related to the mill's design capacity to handle an increasingly low grade of ore from the mines with improved efficiency. Changes to crushing and grinding operations reduced the numbers needed as the number of machines involved was reduced or steps in the process were eliminated. Hand sorting was stopped by the end of 1920 when the management made a decision based on ore reserve estimates to cease trying to produce a distinct first class ore. The final purpose that hand sorting could fulfill -- the removal of scrap iron and other metalic objects that could damage the machinery -- was eliminated with the use of electromagnets. The grinding stones that had been provided by hand sorting were replaced with iron balls which gave better service and could be manufactured on the property from scrap metal. Additional positions in the mill were terminated when crushing operations were transfered to facilities installed underground.[96]

By the time Moodie was replaced as general manager in August 1920, the Britannia operation was considerably more flexible than it had been in 1911. The development of the Fairview mine and the shift to shrinkage stoping allowed the mine to draw on its broken reserves and continue milling at any rate desired for an extended period of time and still cut labour costs by dispensing with large numbers of

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[95] BCDOM, *Annual Report, 1911*, p. 202; *1924*, p. 20.

[96] W. J. Quigly to E. J. Donohue, October 1, 1920 and October 20, 1920, PABC, Add. Mss. 1221, 60/1.

higher cost production miners. As copper prices dropped in the depression that followed the end of the First World War, the reserves allowed the mill to continue producing concentrate at near normal levels while reducing the payroll to 40% of its war-time high of 1,000. Further declines in prices were met with a reduction in mill output and finally, at the end of November, 1920, with a suspension of all work except development for renewed mining. The flexibility that had been built into the system during Moodie's tenure allowed a reduction in operations by stages as the management responded to the copper market. Continued operations were possible at a variety of levels of intensity; mining was no longer an all or nothing proposition.[97]

After Moodie's departure, two interim managers ran Britannia until February 1922 when Carleton Perkins Browning was appointed general manager. Browning had studied at the Columbia School of Mines where he had come into contact with some of the more advanced thinking on engineering and management as applied to mining.[98] One year after his graduation in 1913 he joined the engineering staff at Britannia where he was initially employed as a rodman on the underground survey crew. Thereafter, his rise to positions of greater responsibility was swift; by 1917 he was mine superintendent and shortly thereafter general superintendent. His tenure as general manager lasted until 1948 and encompassed a period of 26 years during which he established a definite style of operation and management within the latitude

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[97] BCDOM, *Annual Report, 1919*, pp. 22, 290; *1920*, pp. 191, 288. In 1920, over 175,000 tons were drawn from the reserves whereas the year before they had been increased by 279,000 tons. By the time operations were suspended on November 30, broken reserves still stood at 1,687,159 tons which would allow Britannia to resume operations at full production whenever it was deemed desirable rather than progress through an extended start-up period as market conditions improved provided the shut-down did not last for years. Henry Leei[?] and C. P. Browning to J. W. D. Moodie, January 1, 1920 and E. J. Donohue to E. B. Schley, March 25, 1921, PABC, Add. Mss. 1221, 1/6, p. 2 and 1/7. p. 5.

[98] See Thomas Thornton Read, *The Development of Mineral Industry Education in the United States* (New York: AIMME, 1941), pp. 175 - 187.

permitted him by the senior management of the Howe Sound Company.[99] During the 1920s he continued to develop and refine programmes begun under Moodie and increased Britannia's production to the highest levels obtained during the life of the mine by extending the mass production capabilities of the mine. He also initiated new policies in hiring and remuneration designed to add another dimension of flexibility to the overall operation of the mine.

The immediate concern during Browning's first years was to erect a new mill to replace the wooden No. 2 Mill which had burned on March 19, 1921. The design and construction supervision of the new steel and concrete 2,500 ton mill was contracted to an engineering firm and site preparation began in June.[100] Even as construction began on the new mill, a second disaster struck the mine. During the night of October 28, flood waters unleashed by heavy rains and the collapse of a log-jam in Britannia Creek devastated the residential district at the Beach with a loss of 36 lives.[101] Due to the shutdown over the winter of 1920-21, the fire, and the flood, the Britannia mine produced nothing during the entire year. The only work on the property consisted of the reconstruction of much of the Beach and the continuation of underground development which followed from Grant Schley's insistent policy of continuing to expand the mine during good times and bad.[102]

When the No. 3 Mill went into operation in February 1923, it was still a hybrid of jig and flotation methods with the continued use of Hancock jigs based on

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[99] *The Miner* 5, 4 (April 1932): 108; and Ramsey, *op. cit.*, p. 84.

[100] BCDOM, *Annual Report, 1921*, p. 227; C. P. Browning to E. B. Schley, March 14, 1922, PABC, Add. Mss. 1221, 1/9, pp. 5, 9, 11.

[101] "Disaster at Britannia Beach," *Mining and Engineering Record* 26, 19 & 20 (October 1921): 207 - 208.

[102] BCDOM, *Annual Report, 1922*, pp. 22, 245.

their efficient performance in the No. 2 Mill.[103] After two months of tests the flotation systems were found to be just as satisfactory as the jigs and their use was discontinued. Thereafter, the unitized plant was operated as an all-flotation process. While the number of treatments applied to the ore as it passed through the mill gave the appearance of a complicated process, in essence the concentrator operated as a straight-line processor: crushed ore from the mine entered the mill, was treated within a closed circuit, and was then discharged at the other end as concentrates and waste.[104]

Throughout the 1920s the mill was the locus of a continuing series of experiments to increase production and lower operating costs. The reagents used in the flotation process were subjected to ongoing tests and selective flotation methods were adopted. The immediate result of selective flotation was to increase the rate of copper recovery and improve the overall grade of the concentrate by depressing the iron pyrites (fool's gold) contained in the ore.[105] By 1927, the mill capacity had been increased from 2,500 to 4,000 tons per day, and the operation of the mill was a demanding metallurgical process requiring close attention from the assay department and other trained technicians. Selective flotation had been further perfected so that once a market was found for the previously useless iron pyrites in the manufacture of sulfuric acid, they were recovered and sold as a separate product. In 1928, the mill was further modified to begin producing lead. Five years later, the process was altered once again so that zinc concentrates could be produced.[106] Gold in the ore presented a

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[103] See Appendix B, Figure 5: No. 3 Britannia Mill, March 1923.

[104] Munro, *op. cit.*, p. 639; and E. A. Haggen, "The Britannia Mine," *Mining and Engineering Record* 27, 9 & 10 (February 15, 1923): 80 - 81.

[105] *Ibid., passim.*

[106] H. A. Pearse, "Three-Product Flotation at Britannia," *The Miner* 7, 3 (March 1934): 92 - 95.

different problem: it could be recovered through selective flotation, but the cost of the operation was prohibitive. Consequently, the pyrite tailings which contained the gold were passed over a deceptively primitive blanket system where the free gold collected much as it did in sluice box operations. While the overall operation was never 100% effective in recovering the mineral in the ore, in 1927 Britannia was earning a high return on a balance of recovery and costs that saved 91.3% of the copper, 62.35% of the gold, and 75.3% of the silver that passed through the mill.[107]

Achieving and maintaining a profitable balance between costs and production levels dominated the operation of the mill throughout the 1920s and into the early 1930s. As new machines and techniques became available or solutions were proposed for local problems, they were systematically investigated and, if found desirable, integrated into the existing plant.[108] As the mineral content of the ore continued to decline, the tonnage capacity of the mill was increased from an average of 2,177 tons per day in 1923 when the average grade was 1.9% copper to 6,228 tons per day in 1931 when the grade had declined to 1.119%. Over the same eight year period, improvements in the flotation circuits increased the percentage of copper in the final concentrates from 14.1% to 26.6%. The balance between the rate of recovery and the cost of the operation performed in an inverse manner: in 1923 the recovery of copper was 91.4% of the assayed content of the ore entering the mill and the cost per ton of ore treated was $0.710; In 1931 recovery was reduced to 87.5% but the cost per ton stood at $0.231.[109]

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[107] H. A. Pearse, "The Concentration of Britannia Ores: A Study of Present Flotation Practice," *Trans. C.I.M.* 30 (1927): 915 - 928. N. B. Pearse was the metallurgist for the No. 3 Mill at the time of writing.

[108] A. C. Munro and H. A. Pearse, *Milling Methods and Costs at the Concentrator of the Britannia Mining and Smelting Co., Ltd., Britannia Beach, B. C.*, U. S., Bureau of Mines. Information Circular No. 6619, May 1932. See "Record of changes made in No. 3 concentrator since 1923," pp. 4 - 5.

Direct labour costs for both operations and repairs in the mill accounted for 38% of total milling costs in 1931; the remaining 62% was charged to power, supplies and reagents. While individual effort no longer had much to do with the productivity of the mill, in terms of tons per man each 8 hour man shift was equal to an average of 108 tons of ore processed.[110] Work in the mill was controlled by pace of the process and was organized around the component parts of the operation as described by A. C. Munro and H. A. Pearse in 1932:

> The supervising staff consists of the superintendent [Munro], the metallurgist [Pearse], and the general crushing plant and repair foreman. The crushing plant is operated by a shift boss, three operators, and five helpers per shift. The grinding and concentrating units are handled by a shift boss, three operators, and three helpers per shift; one operator is employed on ball mills, one for flotation machines, and the other for filters. The flotation operator runs the shift assays and collects and dries the automatic samples. An oiler is employed in both the mill and crushing plant, and a reagent mixer is employed in the mill on day shift only.
>
> Repairs are carried out by a foreman and a crew of five men in the crushing plant and by a foreman and one man in the mill. One electrician and a helper are responsible for electrical maintenance.
>
> Two men are assigned to research and testing work and two assayers handle routine samples and control assays.[111]

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[109](cont'd)[109] *Ibid.* See "Operating costs and concentrator costs for the years 1923 to 1931, inclusive," p. 6.

[110] *Ibid.*, "Table 6 - Summary of milling costs for July, 1931," p. 23 and "Table 7 - Distribution of Labour for July, 1931," p. 24. Britannia reported the lowest concentrating costs of 16 major copper operations survey by the U. S. Bureau of Mines between 1929 and 1931; Britannia's direct labour costs were the second lowest after the Utah Copper Co.'s Magma and Arthur concentrators. Chapman, *op. cit.*, pp. 36 - 37.

[111] Munro and Pearse, *op. cit.*, pp. 15 - 16.

Not counting the mill superintendent and the metallurgist, six supervisors directed the work of 28 mill employees on an average shift. One hundred men spread over three shifts a day processed over 6,000 tons of ore in the mining equivalent of the mass production factory. The output of the mill was flexible in the aggregate and in each of the independent units as it had been in the No. 2 Mill. Consequently, while a certain number of men were required to operate the mill, numbers alone had little to do with the production levels. Output could be increased even while reducing the workforce. If it took 100 men to operate the full mill at 75% capacity one unit could be taken out of production and the same level of production generated by a smaller workforce running the remaining units at full capacity. Any desired daily tonnage below the maximum could be generated through a number of combinations of mill units and labour. Any intimate relationship between manpower and production levels had long passed at Britannia by the end of the 1920s. A similar conclusion may be drawn in regard to the mill workers' skill levels: while the operation of the various machines could be and was learned on the job with helpers eventually moving up to hold positions as operators as vacancies occurred, the important decisions on the operation of the mill was reserved for the mill superintendent, the metallurgist, and, to a lesser degree, the shift bosses. The structure of work in the mill was such that independent decision making on the part of the processing employees was unnecessary and, if exercised, quite possibly counter-productive to the smooth operation of the mill.[112]

Engineering control of the mining operations also expanded during the 1920s as mine production expanded and mining methods were increasingly tailored to the peculiarities of the several ore bodies being worked.[113]

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[112] Chapman, *op. cit.*, pp. 3 - 6.

[113] For the growth of total output during the 1920s see Appendix D: Annual

The information necessary to achieve the increasing sophisitication in mining methods was provided by a widely expanded reliance on the geological sciences. Systematic surveying was undertaken by a consulting geologist in 1922, and the results encouraged the establishment of a permanent geology department at the mine to work in consort with the engineering staff.[114] The functions of the geology department were further expanded in 1925 when Britannia ceased the earlier practice of contracting out its diamond drilling work and began conducting its own drilling programmes. Surface prospecting was also greatly expanded and the search for new ore bodies on the claims was conducted with both traditional and innovative methods.[115]

Diamond drilling and the advancing method of development were combined to extend the Bluff and Fairview mines to greater depths and to bring the Empress and Victoria ore bodies into production. The two new mines were situated to the east of the Fairview mine in soft rock structures which were prone to collapse when mined. In order to protect the workings and prevent cave-ins from diluting the ore, both mines were exploited by means of timbered stopes suited to the ground conditions. Waste rock quarried in a surface glory hole was transported to the timber stopes to support the stope walls after mining so that all ore could be removed and no underground sorting of waste from ore was required. The higher costs associated with these methods were justified by the higher grades of ore found. The Empress and Victoria ores averaged 2.5% copper as compared to the 1.8% in the Fairview mine.[116]

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[113](cont'd)Production Figures, Britannia Mining & Smelting Co., Ltd., 1905 - 1937.

[114] James T. Moore, Jr. to C. P. Browning, "Engineer's Report of Mine Operations for Year Ending December 31, 1922," PABC, Add. Mss. 1221, 1/12, p. 4.

[115] C. P. Browning, "1925 Annual Report," PABC, Add. Mss. 1221, 1/16, p. 69; and James I. Moore, Jr. and Frank Ebbutt, "Electrical Prospecting at the Britannia Mines, " *Trans. C.I.M.* 29 (1926): 84 - 99; and W. G. Joerns, "Diamond Drill and its Uses," *Mining and Industrial Record* 29, 11 (November 1926): 175 - 177.

[116] Browning, "1925 Annual Report," *op. cit.*, pp. 29, 32; C. P. Browning, "Annual Report," February 2, 1924, PABC, Add. Mss. 1221, 1/13, pp. 64, 70; R. A. Wheeler

Shrinkage and glory-holing continued to be the basic methods of opening new ground in the Fairview and Bluff mines although serious problems resulting from the earlier use of the methods were being identified in the upper portions of the Fairview. The deposit consisted of twelve closely associated veins and lodes varying in width from a few feet to 70 feet. A decade of mining the richer sections of these veins had weakened the wall rock to the point where the stopes were collapsing and the entire area was being crushed under its own weight. By 1922, much of the upper workings were so unstable that no mining could be done which left a considerable amount of ore in the stopes that could not be retrieved. The solution to the problem was to treat the entire crushed zone as a glory hole or caved stope similar to those intentionally created by block caving methods. Active preparations for mining the crushed zone commenced in 1924 and by 1927 a surface area of approximately 15 acres was collapsing upon itself and being drawn off from below. The ore recovered in this manner accounted for as much as 37.7% of the total production for 1927. While the inclusion of large amounts of waste rock in the Fairview glory hole reduced the overall grade of the tonnage drawn, the operation was justified by the low costs underground and the ability of the No. 3 Mill to thrive on low-grade ore.[117]

The mining of the Fairview crushed zone necessitated two significant changes in technique. Since not all the ground above the draw points collapsed under its own weight, raises were driven into the stable areas and large powder blasts containing up to 5,000 tons of explosives were detonated to complete the fracturing of the remaining

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[116](cont'd)and James I. Moore, "Engineers' Annual Report of Mine Operations for 1923," 1/14, pp. 30, 33; J. I. Moore, Jr., "Mining Methods at Britannia, British Columbia," *Trans. C.I.M.* 31 (1928): 284; and Swanson, *op. cit.*, pp. 298 - 230.

[117] Moore to Browning, "Engineer's Report, 1922," *op. cit.*, p. 11; Moore, "Mining Methods," *op. cit.*, "1927 Production by Various Methods," p. 287; and C. P. Browning, "1926 Annual Report," January 29, 1927, PABC, Add. Mss. 1221, 1/17, p. 69.

stable ground in the zone. At the time, these blasts were consciously seen as a significant step towards a system of large volume blasting which would give increased tonnages with reduced charges for labour and explosives.[118] Since the collapse of the upper levels tended to produce large blocks of ore that plugged the ore passes and could not be handled by the transportation system, provisions were made for systematic secondary blasting operations. The problem had already been encountered in the Bluff mine and the techniques used there were adapted to the Fairview. A new series of tunnels, or sub-level drifts, were driven between the bottom of the stopes and the haulage levels to provide the miners with access to the ore at a safer place than inside the stopes. In these "bulldozing chambers" large pieces of ore could be drilled and blasted by a miner and a helper when they plugged the transfer raise or failed to pass through a heavy metal grate called a "grizzly".[119]

A second solution to the problem of the crushed zone was based on the recovery of dissolved copper in the mine water that resulted from the leaching action on the heavy rainfall of the region. The same rain and snow that hampered surface glory hole mining permeated the crushed zone and carried a considerable amount of copper out of the mine. Experiments began in 1923 and 1924 demonstrated that the copper could be collected by percipitation on scrap tin on a commercial scale. A permanent plant was constructed outside the 2200 Level Portal and operated on a continuous basis. In 1928, a total of 52,892 pounds of copper was recovered by the method at an average cost per pound of $0.0722.[120]

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[118] Moore to Browning, "Annual Report of Mine Superintendent for 1927," PABC, Add. Mss. 1221, 1/20, pp. 75 - 76.

[119] Moore, "Mining Methods," *op. cit.*, p. 283; C. P. Browning, "1924 Annual Report," *op. cit.*, p. 51.

[120] F. Ebbutt and W. E. Selnes, "The Percipitation of Copper from Mine Waters at Britannia Mines, B. C.," *Trans. C.I.M.* 31 (1928): 290 - 309.

Development of the mine transportaton system continued apace with the opening of new ground and the increase in tonnage to be moved. In 1927, the 2700 haulage tunnel was extended to a point under the Fairview mine and connected to it by a series of rock raises. The connection to the 2200 Level secured access to the other mines. Thereafter, all ores were transported underground and subjected to a primary crushing before being delivered to the mill. Once the system was fully operational in 1928, the surface railway stopped handling ore and was relegated to moving only freight and passengers.[121]

Further refinements in stoping practices were established in the Bluff West mine which opened in 1927. The initial mining plan called for the use of shrinkage stopes and bulldoze chambers which had proved quite satisfactory in the Fairview and Bluff.[122] Practice quickly revealed the unsuitability of the technique since the ground was extremely soft and faulted. Once the stopes were opened, many proved to be unsafe to work in by any method which involved the miners drilling into rock above them. The solution was found to this problem in the technical literature of the year since the Beatson Mine at Latouche, Alaska had experienced a similar problem and described their solution in the *Transactions of the American Institute of Mining and Metallurgical Engineers.*[123] Britannia engineers visited the Latouche mine to investigate the method firsthand. As applied at Britannia, the Latouche system involved undercutting the ore body in the usual way and driving a series of evenly spaced raises through the ore. Once this was completed, drilling and blasting took place from

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[121] BCDOM, *Annual Report, 1927*, p. 362; *1928*, p. 435; and "Chronological Development of Britannia Mines Transportation," BCMM-CF, Transportation system file.

[122] J. I. Moore to C. P. Browning, January 1, 1928, PABC, Add. Mss. 1221, 1/20, pp. 58, 72.

[123] Bevan Presley, "The Latouche System of Mining as Developed at the Beatson Mine, Kennecott Copper Corporation, Latouche, Alaska," *Transactions of the American Institute of Mining and Metallurgical Engineers* 76 (1928): 11 - 52.

stations cut in the raises which meant that no one was required to work under the loose ground in the stope. Otherwise, the broken ore was drawn off as planned.[124]

The shift to truly mass methods of mining at Britannia came about under the pressure of the depression years. Initially, the rapid decline in copper prices that began in 1930 was treated as a short-term fluctuation and was countered by increased production from all mines on the property in an attempt to off set the lower prices with increased earnings from volume sales. By the end of the year the situation was viewed as a long-term problem and the higher cost Empress and Victoria mines were operated on a strictly curtailed basis; the Empress was finally shut entirely. Thereafter, most ores came from the Fairview mine which met the requirements as a low cost producer. At the same time efforts were intensified to develop a site-specific, low-cost, high-volume mining method that would best exploit Britannia's very low-grade ores.[125]

The resulting Britannia mining method combined the elements of caving and large-scale blasting developed in the Fairview crushed zone with the undercutting techniques of the Latouche method except that much larger areas were prepared for mining in any one operation. The general use of bulldozing chambers was incorporated to provide a practical method of handling the ore produced by forced caving. In effect, huge glory holes were created on the surface and underground in such a way that both virgin and previously mined ground could be blasted and drawn off at very low cost. Between 1931 and 1937 when copper prices finally began to rise the Britannia method was used almost exclusively in all large ore bodies while relatively

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[124] C. P. Browning, "1928 Annual Report," PABC, Add. mss. 1221, 1/22, pp. 78 - 80. For details and limitations of the Latouche method see Jackson and Gardner, *op. cit.*, pp. 126 - 129.

[125] E. F. Emmons to C. P. Browning, January 17, 1931, PABC, Add. Mss. 1221, 2/4, pp. 5 - 8.

little work was done in the other areas of the mine.[126] The cost-effectiveness of the method is apparent when the expenses for a ton of ore delivered to the mill are compared for the three mines operating during the depression. The Victoria mine was kept open because it produced the highest grade ores in the mines. Over one twelve-month period square-set methods were used to produce 133,195 tons at an average cost of $1.768 per ton. During the same period the East Bluff mine which had opened in 1931 used the Britannia method to produce 398,664 tons at $0.514 per ton. The major producer -- the Fairview mine - combined the Britannia method with glory holing to produce 1,268,234 tons at $0.370 per ton. In the Victoria mine labour costs were approximately one-half the total cost while in the other two mines labour costs were approximately two-thirds of the total. While the percentages were higher, the actual cash outlay for wages under the Britannia method averaged $0.20 per ton while in the Victoria wages were approximately $0.90 per ton.[127]

While labour productivity in the underground operations never achieved the levels established in the mill, changes in mining practice did raise the overall average tonnage attributable to any one underground worker. The concern with costs and flexibility so evident in the general engineering practice was also applied to controlling direct labour costs paid out in wages during the 1920s. Day wages and the occasional contract had been the norm during the first two decades of operations with the Company raising or lowering the rate in accordance industry-wide standards based on

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[126] C. P. Browning to W. J. Quigly, Janaury 25, 1932, PABC, Add. Mss. 1221, 2/7, pp. 5, 30 - 33. For details of the various applications of the Britannia method see C. V. Brennan, *Mining Operations at the Property of the Britannia Mining & Smelting Co., Ltd., Britannia Beach, British Columbia*, U. S., Bureau of Mines, Information Circular No. 6815, January 1935, pp. 17 - 19; and Chris. G. Dobson, "Blasting Practice in the East Bluff Section of the Britannia Mine," *Trans. C.I.M.* 38 (1935): 322 - 328.

[127] Brennan, *op. cit.*, pp. 33 - 34.

the price of copper. Day wages continued to be determined and paid in the customary way throughout the 1920s, but new policies were instituted which created a series of variable payments in addition to wages. Once again, the desire of the Company in undertaking these changes was to increase the flexibility and productivity of the operation.[128] After 1927 a bonus was available to all employees which was tied to the price of copper: each time the price went up by a certain amount, wages went up, and the converse was true. As a matter of policy these "copper bonuses" were rigidly defined and frequently advertised to the workforce as something separate and unrelated to regular earning. In this way earnings increased while the basic wage was kept unchanged.[129] A second bonus which became available to approximately 75% of the underground workforce after a period of experimentation was tied to productivity and was designed to encourage greater production at an overall lower cost to the Company. These initiatives in labour relations -- or human engineering -- were intimately related to a growing shortage of skilled miners, miners being defined as experts in the art of producing and moving ore in large volumes.

Minor labour disturbances had occurred at Britannia before 1920 but the management -- particularly J. W. D. Moodie - had effectively kept union activities out of the mines and thwarted repeated efforts to organize effective locals of the Western Federation of Miners through a policy of company paternalism and the rapid expulsion of identified union organizers.[130]

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[128] Day wages in all major western copper mines were set by a process of informal consultation among the major producers with Anaconda usually setting the standard in relation to fluctuations in the price of copper. See Britannia's general office files under "Wage Scales", PABC, Add. Mss. 1221, 11/29, 13/18, *passim.*

[129] C. P. Browning, "1928 Annual Report," PABC, Add. Mss. 1221, 1/22, p. 8; and W. A. Matheson, "Memo Re Copper Bonus," February 27, 1937, 71/1.

[130] J. A. Harvey, George Heatherton, and W. E. Barns to Minister of Labour, August 30, 1912, "In the matter of the Industrial Disputes Investigation Act 1907 and in the matter of a dispute between the Britannia Mining and Smelting Company and the

While two locals of the WFM were certified at Britannia, no contract rights were ever established; and after December 1906 the offices of the locals were in Vancouver, not at the mine site. In effect, these local organizations were more a show of presence than an effective representative of the membership in dealing with the management of the mine.[131]

In March 1920, the majority of the underground crew walked out of the Britannia mines in a protest over wages and conditions in the cook and bunkhouses. Once they had left the property, wages were increased by 50 cents per day and changes were made in the living accommodations. The men, however, were not taken back; instead, "The force was maintained below normal requirements for some months in order to keep out undesirables...."[132] In 1921, another wage reduction resulted in "those few who objected to reduction [being] marked for early attention."[133] In 1922 operations were suspended entirely for a brief period of time and when the mine reopened, Britannia was unable to attract skilled underground workers. Many had left the Vancouver area or had gone into other lines of work during the post-war depression. The shortage of skilled mine labour was a general problem throughout the mining industries and hardly unique to Britannia. Thus, when Browning assumed the management of the mine he was faced with the task of acquiring a work force, using the few skilled men available to train them, and provide them with sufficient motivation to stay.[134]

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[130](cont'd)Britannia Miners' Union," Rossland Historical Museum, Sandon Historical, file 20.

[131] See "Directory of Local Unions and Officers," *Miners Magazine*, various issues, 1906 - 1914; and George Heatherton, Report to 13th Annual Convention of District 6, WFM, [1911], Rossland Historical Museum, Local 480 - Mine, Mill, file 38.

[132] E. J. Donohue to E. B. Schley, March 25, 1921, PABC, Add. Mss. 1221, 1/7, pp. 16 - 17.

[133] Quigly to Donohue, January 5, 1921, PABC, Add. Mss. 1221, 60/1.

The shortage of "competent" underground labour continued to plague Britannia throughout 1923 despite the Company's efforts to augment its own recruiting agents with the services of the provincial government's employment service. The desire to attract reliable workers sometimes conflicted with the need to obtain skilled miners. While the changes to engineering practice could, and did, increase the efficiency of the mine, some method of motivating the underground labour force to work dilligently with minimal supervision was required. All solutions proposed involved breaking with the day wage system that had prevailed in the western mines for fifty years.[135]

Even though contract work had not been a significant feature in the miners' earnings, it had been used on an occasional basis during the mines' first twenty years. In general, it had been found to be an unsatisfactory means of controlling costs and contracts awarded were sometimes cancelled due to excessive costs.[136] Generally, the object of a contract was to have an unusual job such as an exploration raise or drift done for a set price; the contractor made money if he completed the work in less time than estimated by the Company. In most cases contracts did pay more than the miners would have made if the work had been undertaken on a day rate.[137] Detailed knowledge of working conditions and the expected results were generally lacking which made the setting of contract prices an arbitrary undertaking. The contractors, on the other hand, were usually insistent that the Company ensure predictable working

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[134](cont'd)[134] C. P. Browning, "1922 Annual Report," PABC, Add. Mss. 1221, 1/11, p. 3; and *Mining and Engineering Record* 28, 1 (March 25, 1925): 18.

[135] C. P. Browning, "1923 Annual Report," PABC, Add. Mss. 1221, 1/13, p. 1; and 11/28, *passim.*

[136] S. Ford Eaton, "Driving a 1,200-Ft. Raise." *Mining and Engineering Journal* 102 (September 9, 1916): 461.

[137] Contract Book, November 1918 - November 1921, BCMM. Out of 61 contracts described for the three year period, 53 carried a balance due after charges were made for wages paid and explosives, 2 never started, and 6 were finished at a loss to the contractor.

conditions so as to avoid unpaid down time. Generally, this meant that they desired to be supplied with tools in good working order and supplies when required. Browning was not always able to meet such requirements during his first years as manager and on several occasions cancelled all contracts when the mine was unable to supply such essential services as steady supplies of compressed air and explosives.[138]

During 1923, Britannia initiated a series of experimental contract/bonus system programmes, "In order to attract a better class of labor and produce lower costs...." While no definite results were obtained during the first year, it was decided to continue and expand the experiments.[139] As information was collected which enabled to Company to make a determination of what "constituted a fair day's work," the decision was made to divide the work in the mines into three broad categories: company time, bonus work, and contract work. The initial emphasis was placed on the contract system since it promised to provide the most rigid control on costs. Attempts to put production drilling on contract in a few test stopes failed miserably: "There was little if any reduction in cost, or improvement in performance. The miners were not pleased with the system, though it met with no active opposition; they were merely uninterested." A second attempt in the fall of 1923 met with a little more cooperation and enabled the engineers to secure some valuable information on performance standards for stoping and tramming.[140]

Even with a few limited successes, Browning's initial contract system had its faults. He was well aware that the system, as it stood, might just as easily undermine morale in the mine as increase performance.

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[138] C. P. Browning, "1923 Annual Report," PABC, Add. Mss. 1221, 1/13, p. 3.

[139] R. A. Wheeler and James I. Moore, Jr., "Engineers' Annual Report of Mine Operations For 1923," PABC, Add. Mss. 1221, 1/14, p. 1.

[140] C. P. Browning, "1924 Annual Report," PABC, Add. Mss. 1221, 1/15, p. 103.

> It was only, however, in the spring of 1924 that real progress was made when new machines [which did not break down so often] were introduced (in the Thomas stope). The miners in this stope earned on contract amounts considerably in excess of company wages, though the contract prices were considerably below earlier costs in this working place. The advantages accruing from improved performance was offset by the unfavourable effect on the workmen of cutting the contract prices, a procedure which unfortunately was necessary as standards improved, not only in the breaking, but in the haulage contracts. A continuation of the contract system, with the consequent cutting of prices as standards improved, would have ruined the morale of the organization and would have rendered attempts at further improvement through the use of contract or bonus systems useless.[141]

The alternative was a true bonus system where the workers were guaranteed their day rate and paid extra for production above a set standard. The setting of the standards was an engineering problem to be solved using records of past performance that had been built up during the contract experiment and through the use of time studies. When the contract system was abandoned, the haulage of ore in the mine was the first job to be put on the bonus system since the railway-like operation allowed a quick establishment of standards. Thereafter, other areas of the mines were incorporated until a full 70% of the men in the Fairview and Bluff mines were on bonus.[142]

A second objection to the contract system lay in in the Company's obligation to pay the agreed price no matter how quickly the job was done. To Browning's mind, "This is not a fair distribution of savings due to increased performance." And cutting the rates was not good for morale. The bonus system, however, could tolerate greater tinkering with the rates once the concept was embraced by the workers. "The system is sound in that the greater the unit production, the more bonus the workmen

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[141] *Ibid.*, pp. 103 - 104.

[142] *Ibid.*, p. 104.

make and the greater the savings to the Company."[143]

The effectiveness of the bonus as a motivater was demonstrated in numerous applications. In one stope the tons broken per manshift increased from 32 to 57 during the first three months of operations under the bonus. There were no significant alterations in the ore mined or the method of mining. On one short tram haul the tons transferred from the draw points to the rock raise increased from 75.2 in January 1924 to 137 in December. More importantly from the Company's point of view, the cost of the bonus per ton decreased on that tram from 7 cents to 3.4 cents over the same time period. The trammers increased their income, production rose, and the Company paid less for what it got. The effect on production was significant enough that Britannia increased its total tonnage mined and trammed in 1924 to 810,357 tons from 682,511 tons the previous year at the same time that the size of the mine crew was reduced. Overall, tons drawn from the stopes increased from 4.75 per manshift in January to 5.60 in December; and tons broken, ie. drilled and blasted, increased from 16.7 to 26 for a yearly average of 20.5.[144]

In order to make the bonus system palatable on a continuing basis a bonus department was created within the engineering department; and a bonus engineer was charged with ensuring that all conditions of work -- hardness of rock, wetness of ore, distance of tram, and any other factor that could affect performance - were known by the workmen to be taken into account and regularly adjusted.[145] Extensive records were kept, and all new equipment was taken into account in the setting of rates. Time studies were abandoned in 1926 due to the basic assumption "that workmen might cut

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[143] *Ibid.*, p. 105.

[144] *Ibid.*, pp. 48, 61, 107. See also Appendix D.

[145] C. P. Browning, "1926 Annual Report," PABC, Add. Mss. -1221, 1/17, p. 88.

down their production during the trial period hoping for a lower standard."[146]

Once the system was fully operational, one-quarter to one-third of the total savings generated by the extra production was paid to the workmen involved depending on their job classifications. These awards were admittedly arbitrary:

> In defense of these fractions it can be said that the setting of normals can never be an exact science and a safety factor is necessary. In figuring the bonus on account of these fractions all breaks are given in favor of the workmen. Were the fractions made 1/2 in each case normals must necessarily be put higher to avoid bonus being paid out of proportion to the extra effort expended in the case of exceptionally good conditions being encountered.[147]

In a move designed to reduce the volume of records kept, the bonus system was modified in 1926 so that all members of the same crew in a given workplace were paid the same bonus regardless of occupation. The gross earnings of the crew were posted for all to see to create a sense of common interest and competition between crews. Efforts to extend the grouping principle to larger units, such as each shift in the mine, were briefly tried and abandoned after it became apparent that the individual bonus was the greater incentive. Overall, the bonus system was a success from the Company's point of view during the 1920s since production was up, unit costs were down, and the labour turnover was decreasing.[148]

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[146] James I. Moore, Jr., to C. P. Browning, Janaury 1, 1927, PABC, Add. Mss. 1221, 1/18, p. 22.
[147] *Ibid.*, p. 24.

[148] *Ibid.*, p. 37. Attempts were also made to encourage safety through the use of separate safety bonuses tied to small group performance. The effort met with little success and was abandoned.

With the detailed performance information gained through the operation of the bonus system it was possible for Britannia to re-introduce contracts for the more difficult types of development work such as raise driving. In general, contracts became common in areas of the mine where little direct supervision was provided. Consequently, contracts were awards to those who were recognized as superior or skilled miners capable of independent action.[149] This group was a minority in the mines; most production miners did not qualify for contracts since they were involved in repetitious activities not requiring frequent decisions outside the area of training for the job. While precise numbers have not been discovered to document the ratio of contract (skilled) miners to bonus (production) miners, the amounts paid out above wages to the two groups are suggestive In 1927, a little less than $12,000 was paid out to the contract miners while $29,000 was distributed to production miners as bonus payments. The contract miners accounted for 41% of the total paid out as incentives. Since their average earnings were generally higher than those of the production miners, it may be assumed that skilled miners accounted for no more than 30% of the total underground workforce.[150]

The application of the bonus system began to be questioned by the officers of Britannia's parent company, the Howe Sound Company, in 1929. In their estimation the system of setting standards had become lax during the period of rising copper prices that characterized the first part of 1929. Complacency was suspected and feared: "... that in carrying out this bonus system we are falling into a rut in its application."[151] Despite detailed explanations of the bonus formulations, the New York office remained

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[149] Moore to Browning, *loc. cit.*, p. 23.

[150] "Annual Report of Mine Superintendent for 1927," PABC, Add. Mss. 1221, 1/20, p. 22.

[151] W. J. Quigly to C. P. Browning, January 29, 1929, PABC, Add. Mss. 1221, 70/26.

unconvinced and began to exercise a greater degree of direct control over the system by reserving the right to expect a detailed explanation of all "significant variations from the usual standard."[152]

After the price of copper began to fall in May 1929, the bonus question took on a new direction. By May 1930, the continued drop in the price had eliminated all bonuses tied to the copper price which effectively reduced the wages of all employees by at least $25.00 per month. The action was taken with little protest due to the increasing unemployment in the mines and the consistent policy of identifying the bonuses with the copper price, not with wages.[153]

In 1930, both production bonuses and contract work were discontinued while Britannia reviewed the performance standards. Subsequently, all bonus work in the small, square-set Victoria mine was stopped as the management opted for close supervision of a greatly reduced workforce to ensure production standards. In the larger Bluff and Fairview mines workers in the chutes and bulldozing chambers also had their bonuses stopped with the explanation that the levels of individual production had always been an approximation. The use of gravity to move the ore through major portions of the mine was cited as the reason for the imprecision of the measurements. A similar case was used to cut off bonuses in the caving stopes. By the end of 1930, the decision had been made to severely limit the use of the bonus in the future and rely on contracts and direct supervision to control a drastically reduced workforce.[154]

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[152] Moore to Browning, February 9, 1929; Bonus Department to Moore, [circa February 1929]; and Quigly to Browning, July 26, 1929, PABC, Add. Mss. 1221, 70/26.

[153] See "Copper Bonus, 1929 - 1952" file, PABC, Add. Mss. 1221, 71/1, *passim.*

[154] C. P. Browning, "1930 Annual Report," PABC, Add. Mss. 1221, 2/3, pp. 8, 93, 96 - 97.

The elimination of all bonuses reduced direct labour costs throughout the depression with only minimal adjustments to the day rate; and the development of the Britannia mining method allowed the reduced labour force to continue to increase its productivity. Between January 1931 and January 1932 the mine payroll was slashed from 1,131 to 495. During the same period of time the average cost per ton of ore mined dropped from $1.05 to $0.38 due to the concentration of efforts on mining the large, even lower-grade ores.[155] By the end of 1932, all mines at Britannia were closed with the exception of the East Bluff where the Britannia method was used exclusively.[156] Mill costs were also reduced through layoffs, increased system efficiency, and intermittent operation.[157] Until copper prices began to rise in 1937, incentive bonuses were rarely used except in very limited applications such as shaft sinking. It was the opinion of the management that "under present conditions the lowest cost can be maintained by well supervised work on a day's pay basis."[158] Considering the reduced size of the mine crews and the widespread unemployment, it was a reasonable assumption.

Nevertheless, the patterns of "modern mining" had been set, and as the copper mining industry revived both incentive bonuses and copper bonuses were reintroduced. Their elimination during the 1930s was a product of intense pressure on costs in an industry that could not control its product prices. Once the price pressure was relaxed the incentive system was revived and its use continued into the following decades as an essential leg of the triangle of engineering practice that epitomized "modern

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[155] Between January 1, 1929 and December 31, 1931 the average grade of ore produced at Britannia dropped from 1.282% copper to 0.887%. C. P. Browning to W. J. Quigly, Janaury 25, 1932, PABC, Add. Mss. 1221, 2/7, p. 4.

[156] C. P. Browning, "1932 Mine Report," PABC, Add. Mss. 1221, 2/11, p. 4.

[157] C. P. Browning, "1931 Mill Report," PABC, Add. Mss. 1221, 2/8. pp. 1, 11.

[158] C. P. Browning, "1932 Mill Report," *loc. cit.*

mining:" mining, metallurgical, and human engineering.[159]

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[159] The records of the Britannia local of the International Union of Mine, Mill, and Smelter Workers -- Local 663 -- suggest a constant concern with the application of bonuses and contracts from the moments of certification in 1943. Labour-management committees and Underground contract committees formed important elements in contract negotiations until the end of the Howe Sound Company's association with Britannia in 1958. Under the subsequent Anaconda management, incentive bonuses continued to be a central feature in labour-management relations. See Mine-Mill Papers, UBC Special Collections, 116/1-6, 117, *passim*; and Anaconda Company (Canada) Ltd., Western Division, "Incentive Manual," 115/4, *passim*.

Conclusion

In his *The Unbound Prometheus*, David S. Landes noted that the "reorganization of work entailed reorganization of labour: the relationships of the men to one another and to their employers were implicit in the mode of production; technology and social pattern reinforced each other." This was especially evident in the drive for efficiency that increasingly characterized industry in the early decades of the twentieth century. Landes also observed that the measurement of labour productivity as opposed to the efficiency of a machine was a major problem in the introduction of mass production techniques: "... labour is not a factor like other factors. It is active where equipment and materials are passive. It has a mind of its own; it resists as well as responds."[1] Thus, the integration of labour and machinery into interlocking systems was the engineering triumph essential to the success of mass production techniques in mining as in other industries.

Mechanization, alone, was insufficient to bring about the increase in productivity necessary for mass production or mass mining. Tools and people had to be organized into new configurations that best utilized the capabilities of the available elements. The distinction between selective and non-selective mining is illustrative. Machine drills

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[1] David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge: Cambridge University Press, 1970), p. 317.

could speed up the rate of mining under selective methods but the volume of ore produced was still small since the method placed the greater emphasis on procuring high-value ores. Under non-selective practice, the use of the drill was redefined so as to produce the largest possible volume of acceptable ore with the least expenditure for labour and supplies.

Mining methods were also chosen on the basis of the qualities and quantities of the ore that the mine expected to produce. The often elaborate and expensive square-set timber structures that made the Comstock Lode possible and famous did more than simply keep the ground from collapsing on the miners. Selective mining involved intense sorting of the broken rock at several states with the first sorting taking place in the mine immediately after blasting. Square-sets provided a working platform for drilling, blasting, and sorting; they also provided in their lower levels a place to store the waste rock sorted from the ore. Shrinkage stopes continued to supply a working platform, but they were only practical if no sorting of the ore took place in the stopes. Block-caving techniques such as the Britannia method removed workmen from the stopes entirely. Blasting and drawing ore was done from tunnels that surrounded the stope which now served solely as a collection point for the broken ore.

Since the change from selective to non-selective mining methods was conditional on the ability of the milling and concentrating operations to recover sufficient copper from the lower-grade ores and still produce a profit, there is a tendency to credit the impetus for the success of the transition to dramatic changes in concentrating technology. While the wide-spread use of flotation machines in the 1920s did significantly raise the rate of copper recovery, the intial successes with the mass mining of copper were established well before the introduction of flotation as standard practice. Only minor changes in gravity concentration methods and smelting techniques

accompanied the shift to mass mining at Granby's Phoenix mines and Utah Copper's operations in Bingham Canyon. Milling losses continued to be high, but they were offset by the copper recovered from the greatly increased volumes of ore passing through the mill. Innovations in machinery played an important role in the success of low-grade mining, but it was the selection and organization of machines and methods into systems designed to strike a profitable balance between lowered cost and increased volumes that was decisive.

The coalescence of greater degrees of mechanization and increase scales of operation into a rational and potentially profitable form involved the elimination of some jobs, the fragmentation of others, and the development of a system of smooth flowing, sequential operations that could be conducted, in the main, by unskilled or semi-skilled labour.[2] In the mill and concentrator, improvements to the existing gravity machines and the reorganization of flow sheets reduced the numbers needed to operate the plant at the same time that they marginally increased the recovery of copper. The shift to larger volumes of low-grade ores eventually eliminated the skills needed to recognize ore from waste on the picking belts as the belts were removed from the system. And the construction of unitized mills with partial or all-flotation systems ended any direct correlation between crew size and overall productivity.

Underground work also underwent a similar transition. Skilled miners continued to be a component of the mine labour force, but they were increasingly relegated to tasks which had not been standardized; and their numbers decreased. The great majority of mine workers performed limited or single, repetitive tasks in the larger mines -- drilling, blasting, chute pulling, or tramming -- which had once been component parts of the miners' overall skills. Before the First World War increases in

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[2] Landes, *op. cit.*, p. 307.

output were directly proportionate to increases in employment. The adaptation of new mining systems such as shrinkage stoping reduced the ratio of men to tons mined, but once the system was in place increased output under the new methods once again involved increased employment. The successful implementation in the western mines of the bonus/contract system finally broke this relationship; and during the 1920s general mine production increased while employment declined. Bonus systems which were a direct result of engineering studies enabled both the mine worker and the mine operator to increase their earnings due to improved production and reduced operating costs. Furthermore, incentive plans and the extensive record keeping associated with them provided an indirect means of supervising the work of a labour force that was often scattered about a large area. It was no longer necessary to exercise close control over the men by means of a small army of supervisors, shift bosses, and foremen. Nor was it necessary to rely on the skills of the miner. The supervising staff had simply to set the men to work at specific tasks and ensure that they were properly supplied with the necessities of the job. Production records collected under the bonus schemes would tell the rest.

Perhaps the most important engineering change in mining practice between 1900 and 1930 was the establishment of flexible mining/milling systems that allowed the several component parts to operate semi-independently of each other at levels most conducive to continual operations and profits. Due to the ability to stockpile large quantities of ore underground, higher cost mining operations could be curtailed or stopped altogether in response to falling copper prices while the less costly transportation and milling systems continued to operate and generate revenue. Conversely, but less commonly, the mine could stockpile ore for processing at a later date when metal prices might be higher. In either case, regular employment in the mines became less of a certainty except during periods of high copper prices.

By the beginning of the twentieth century the definition of a miner had already undergone significant changes. The "jack-of-all-trades" or "all-round miner" had become the specialist in drilling or timbering or tramming as the mines increased in size and complexity. As the tasks became standardized and repetitious, the specialist was transformed into a semi-skilled machine operator who could be replaced by a new man with only a minimal amount of training since the task involved doing one thing over and over again. The skilled underground miner who could perform a wide range of jobs with a minimum of supervision continued to be a feature of the mines; but he was used in development work and other situations where unknown conditions might be encountered. The skilled miner working in relative independence was a breed apart from the mass of production mine workers who did their individual tasks with the end result that the tonnages desired by the mines' engineers were produced in the desired manner.

Any suggestion that the major impact of technological change on labour in the western mines occurred with the initial mechanization of mining or that the patterns of labour usage were established by the early years of the twentieth century ignores the subsequent rise of mass mining and milling techniques and the successful institution of contract/bonus methods of renumeration. As the discussion of the technological aspects of the Britannia mines suggests, technological change was an ongoing process with a continual impact on mine labour. The rate of change varied due to the restraints imposed on change by the need to invest sizable sums in the restructuring of a mine; but, over a thirty year period, Britannia moved from selective to non-selective mining and from a high degree of dependence on the skilled miner to an even greater dependence on the technically trained engineer. As the "Second" Industrial Revolution took hold in the copper mining industry, the traditional skills of the miner were superceded by the methodical, cost-conscious approach of the engineer.

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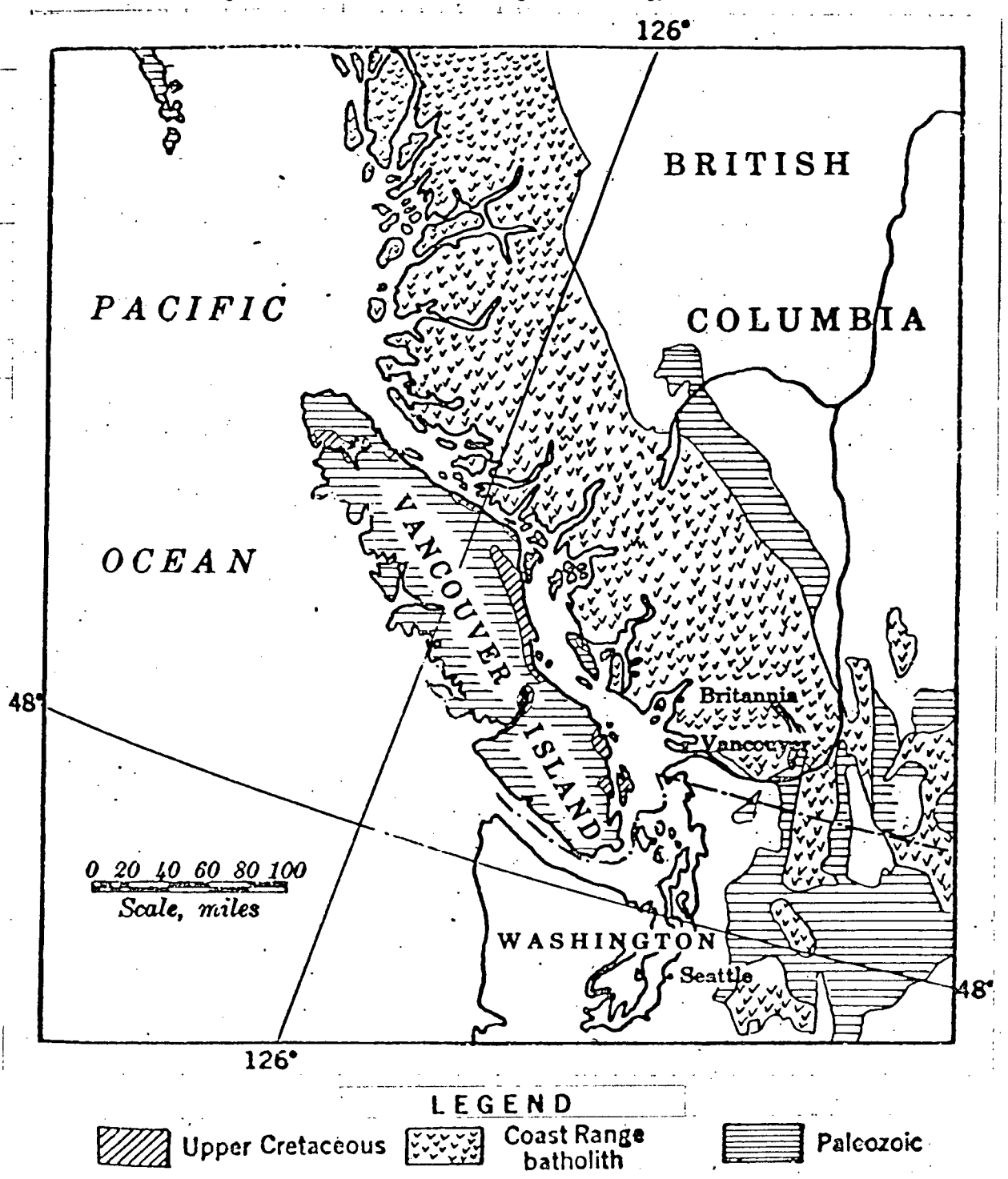
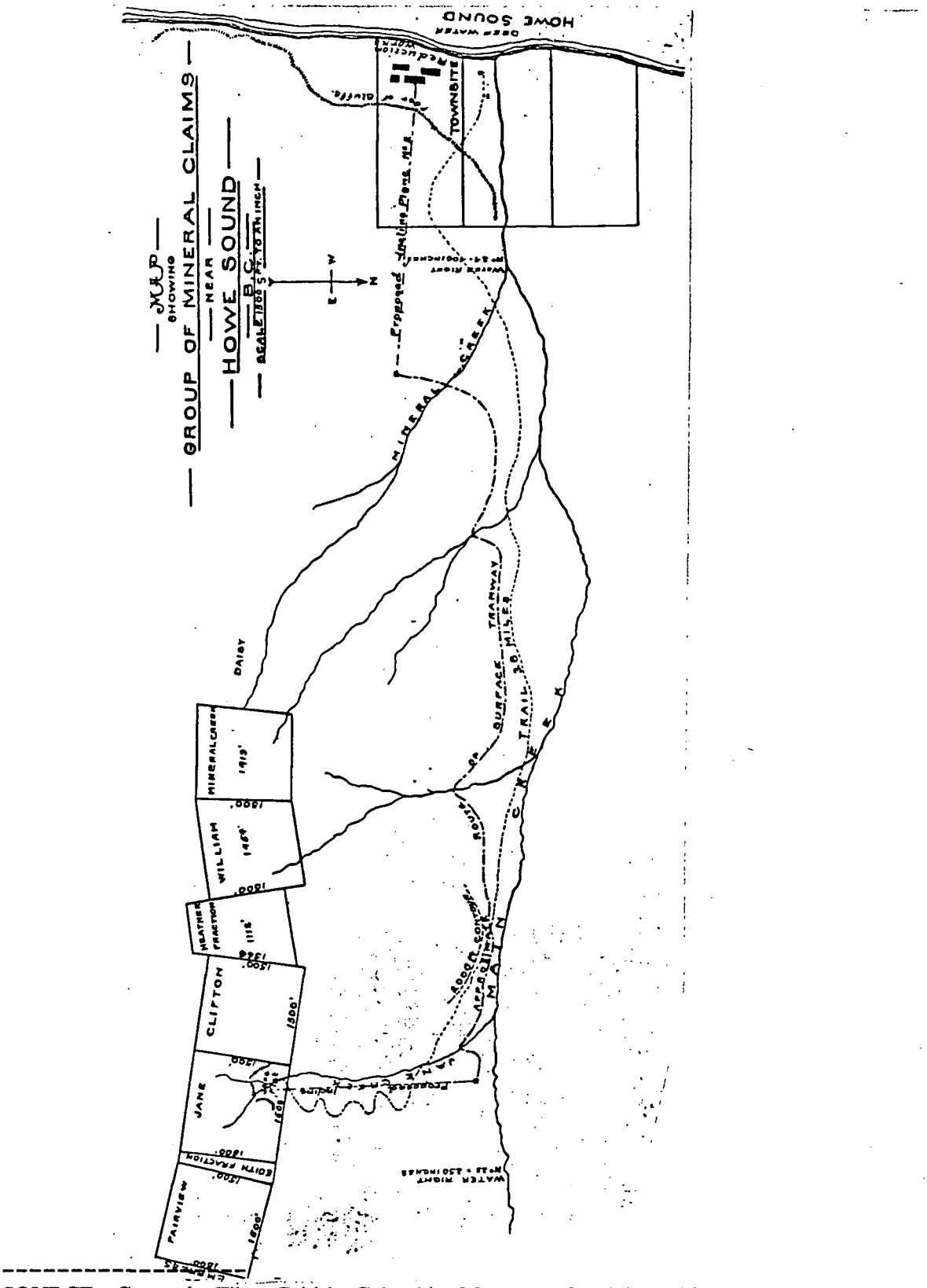
Appendix A: Maps and Plans

Figure A-1: Location and Regional Geology, Britannia Mines



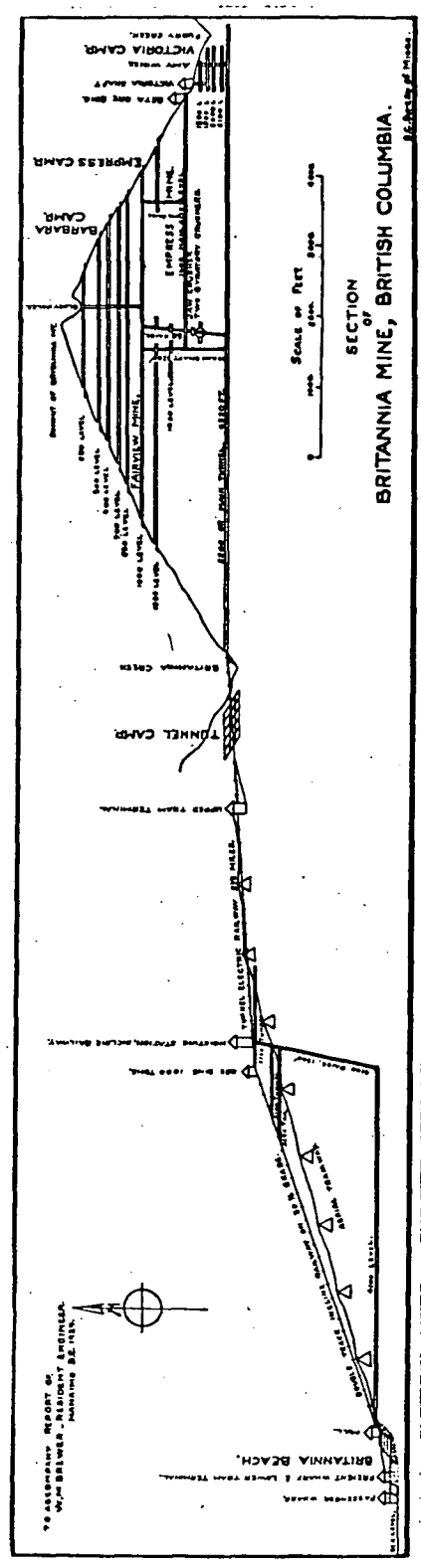
SOURCE: Reproduced from C. V. Brennan, *Mining Operations at the Property of the Britannia Mining & Smelting Co., Ltd., Britannia Beach, British Columbia*, U. S., Bureau of Mines, Information Circular No. 6815, January 1935, following p. 2.

Figure A-2: Britannia Claim Group With Early Development Proposals, Circa. 1900



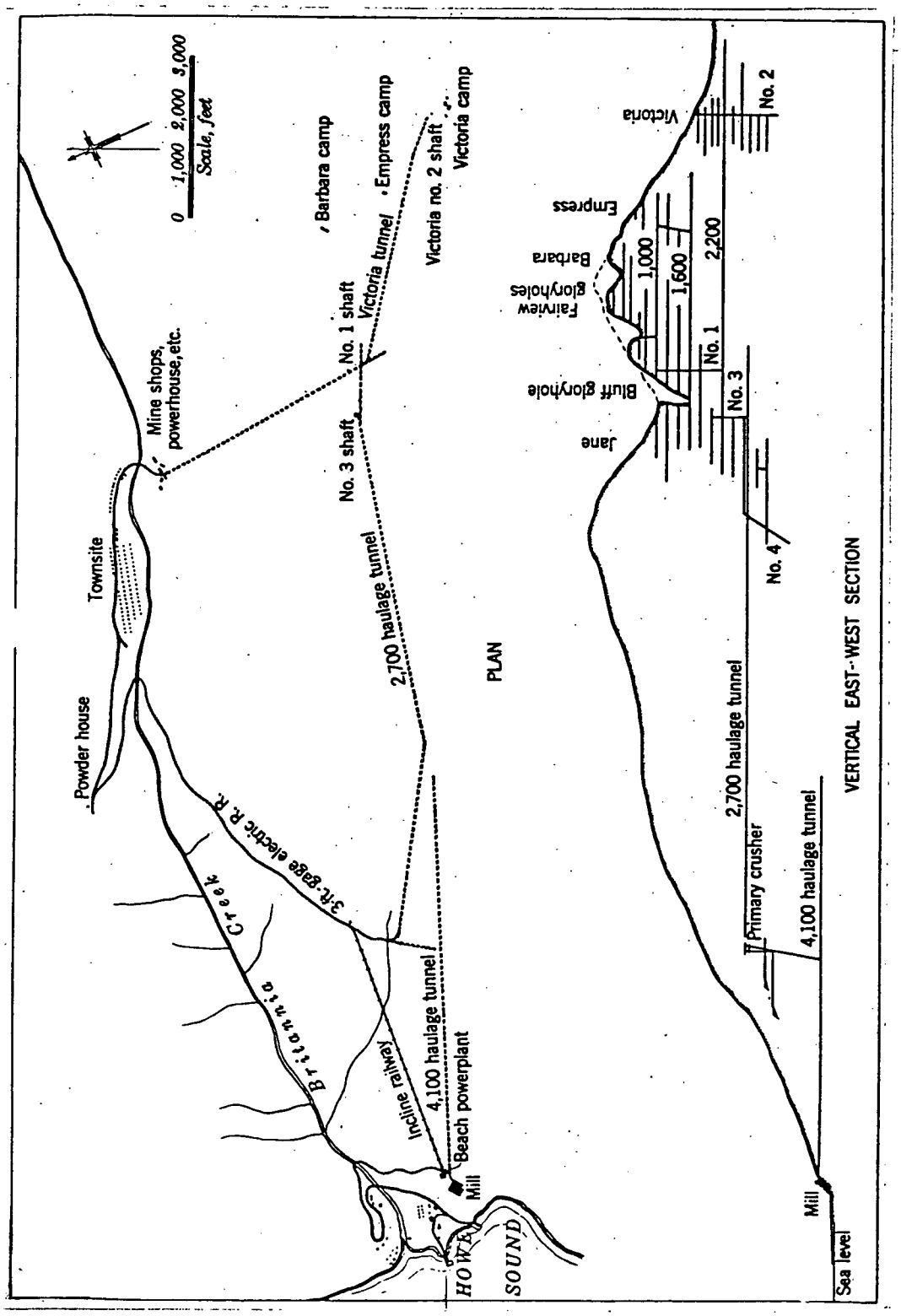
SOURCE: Curator's Files, British Columbia Museum of Mining, Discovery File No. 2.

Figure A-3: East-West Vertical Section, Britannia Mines, 1924



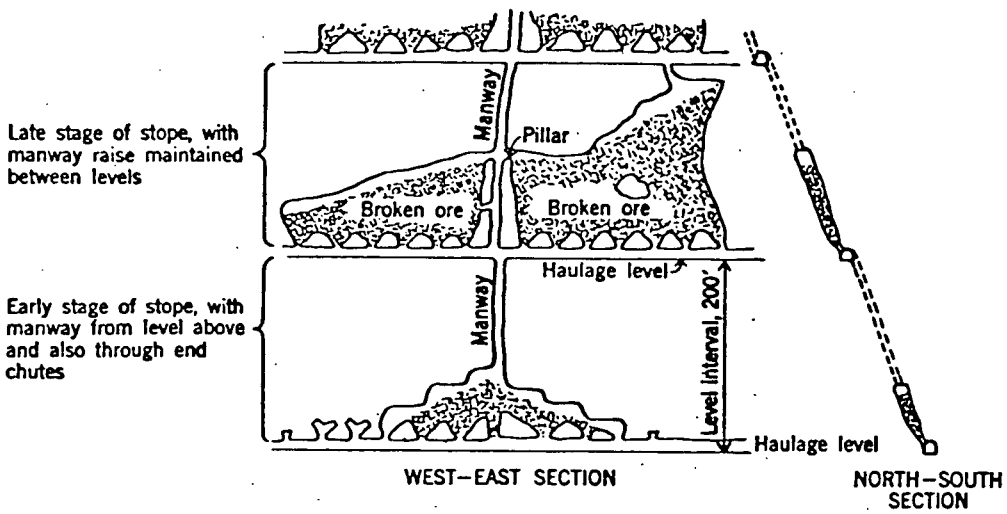
SOURCE: British Columbia Department of Mines, *Annual Report, 1924*, p. 235.

Figure A-4: Plan and East-West Vertical Section, Britannia Mines, Circa. 1935



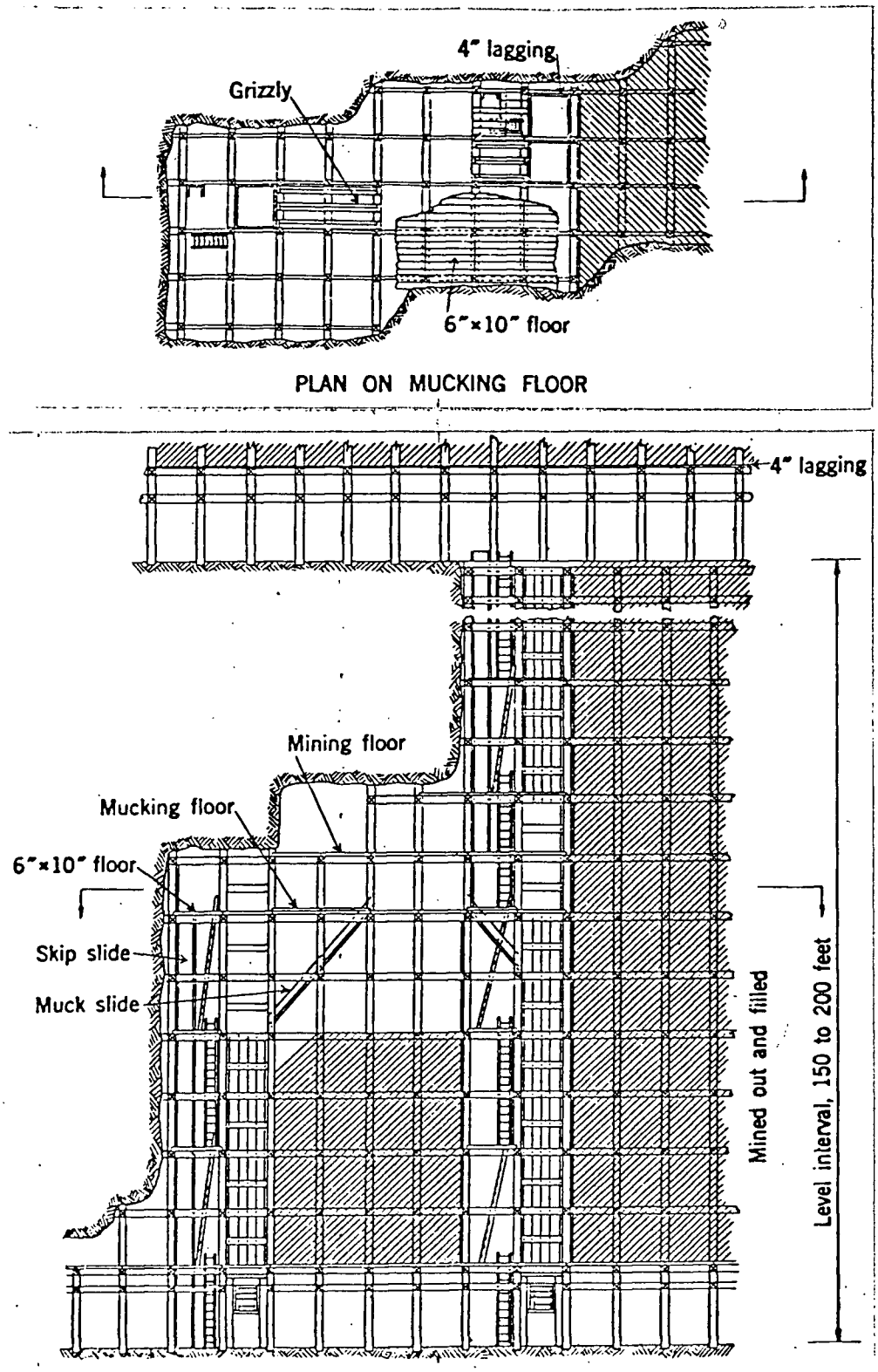
SOURCE: Brennan, *op. cit.*, following p. 6.

Figure A-5: Ideal Section of Fairview Shrinkage Stope



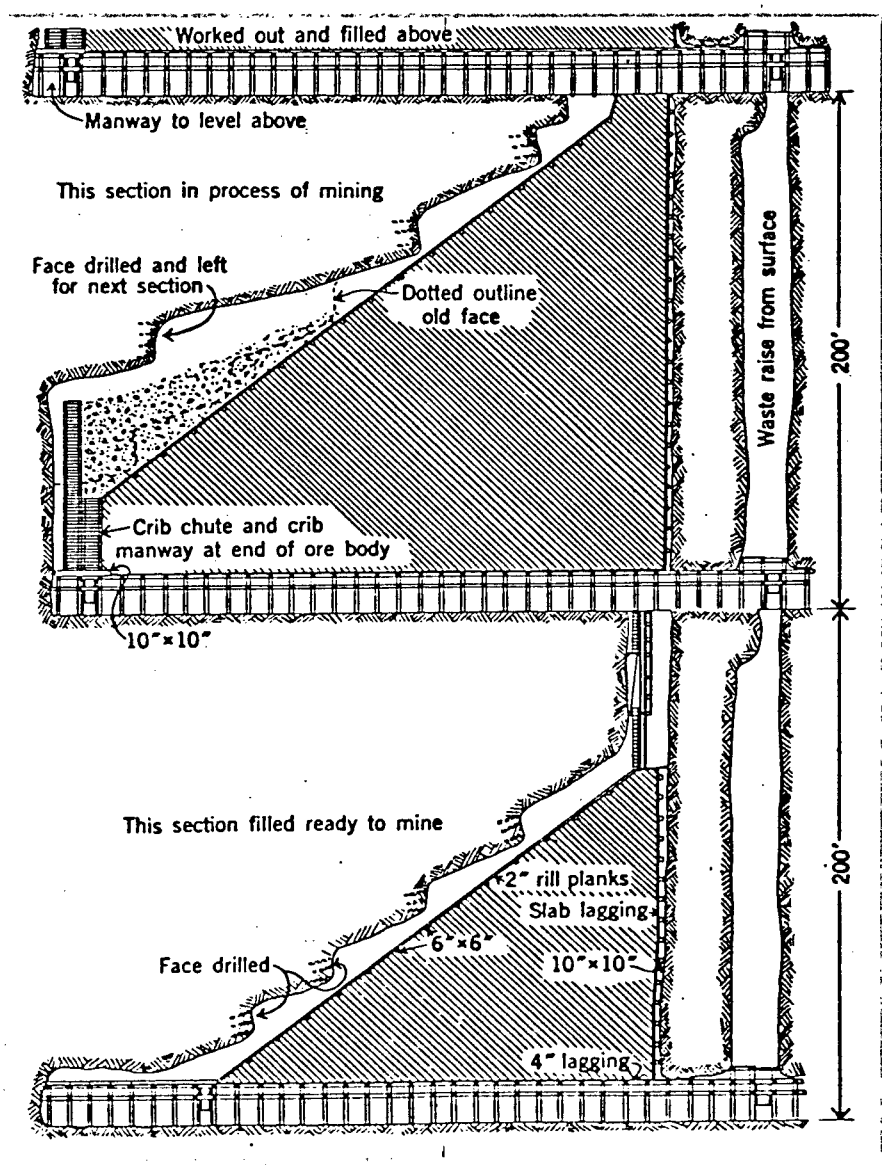
SOURCE: *Ibid.*, following p. 14.

Figure A-6: Ideal Plan and Section of Victoria Square-Sets



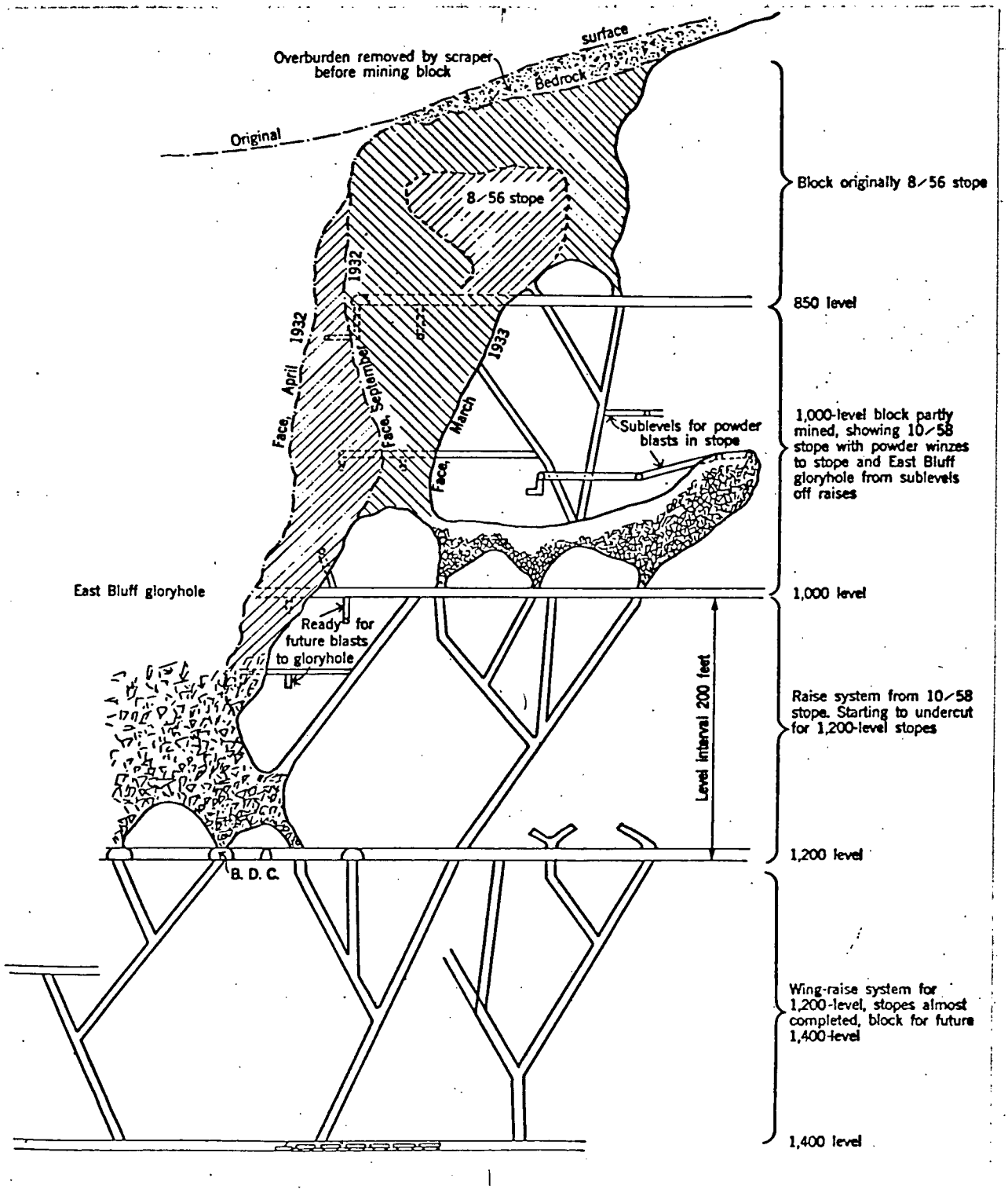
SOURCE: *Ibid.*, following p. 14. Very similar timber-sets were used to open the Jane Mine.

Figure A-7: Ideal Section of Victoria Rill Stopes



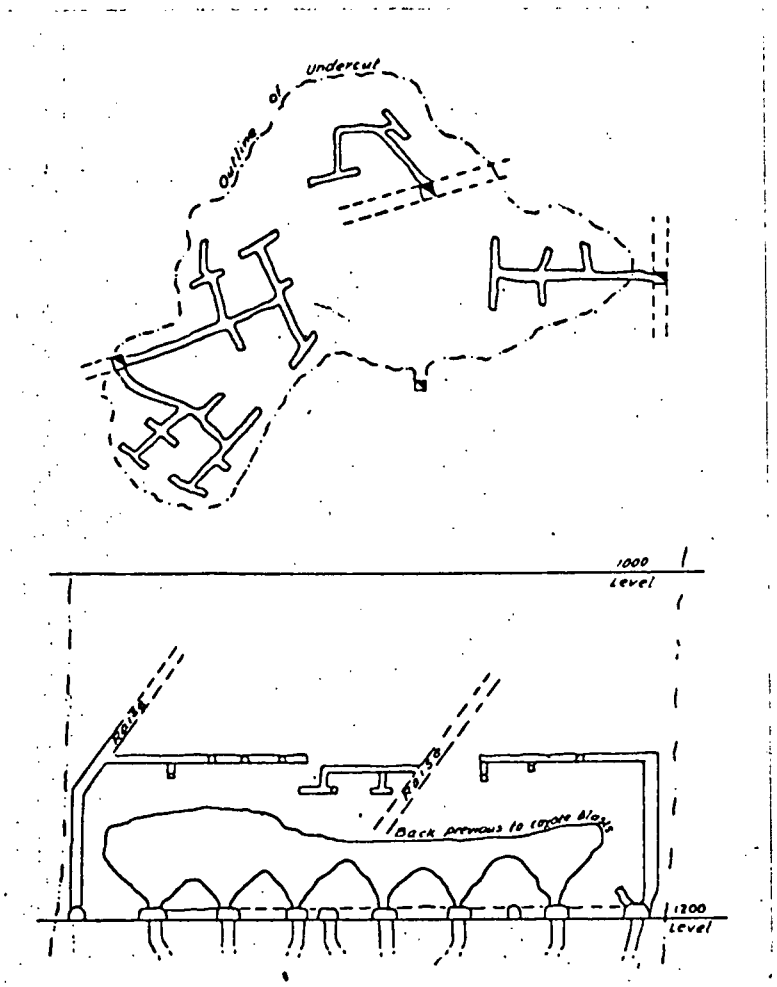
SOURCE: *Ibid.*, following p. 14. Rill stopes were used in narrow veins when the wall rock was weak and prone to failure.

Figure A-8: Ideal Section of East Bluff Using Britannia Method



SOURCE: *Ibid.*, following p. 18.

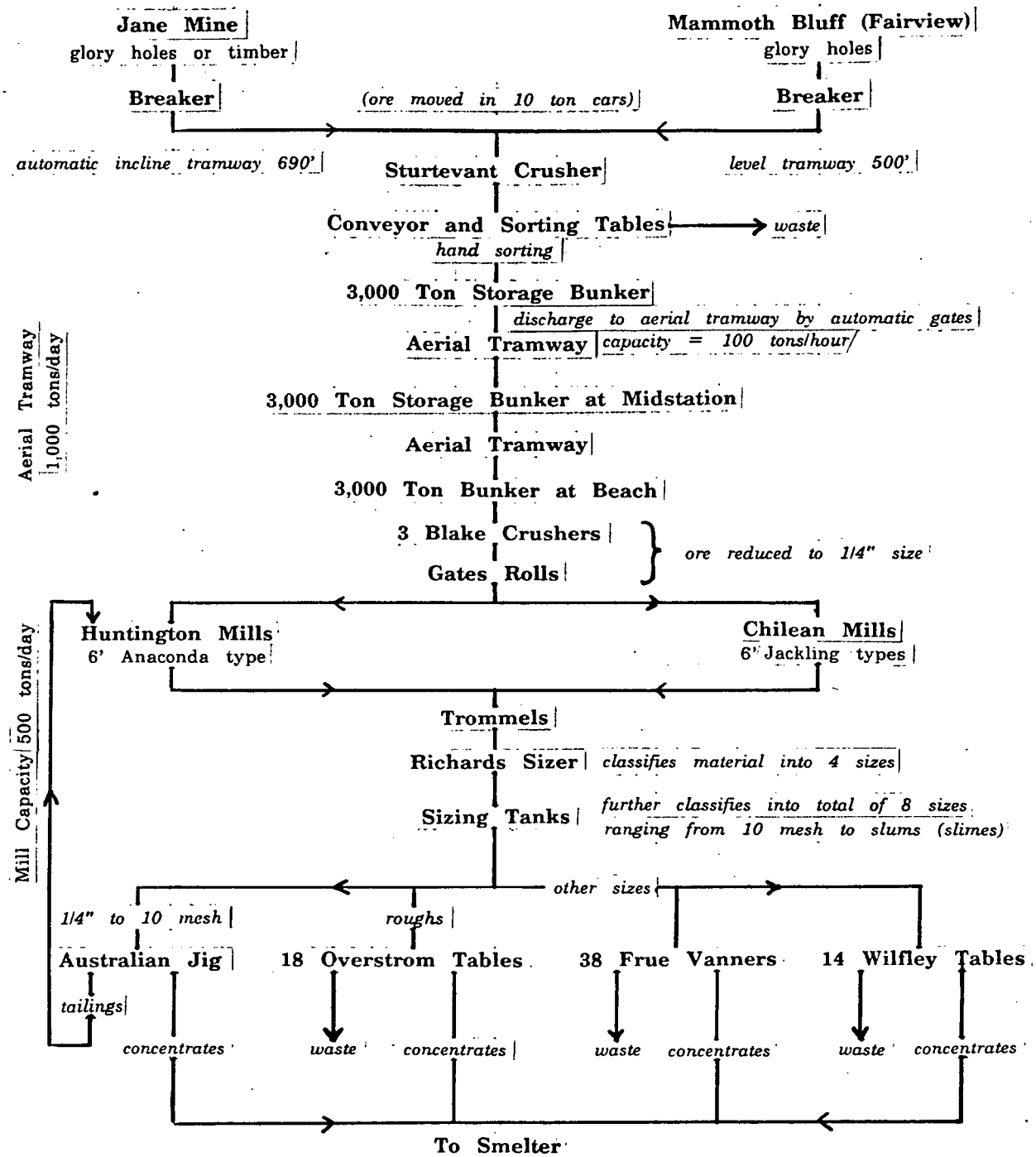
Figure A-9: Ideal Plan and Section of East Bluff Using Forced Caving



SOURCE: Chris. G. Dobson, "Blasting Practice in the East Bluff Section of the Britannia Mine," *Transactions of the Canadian Institute of Mining and Metallurgy* 38 (1935): 327.

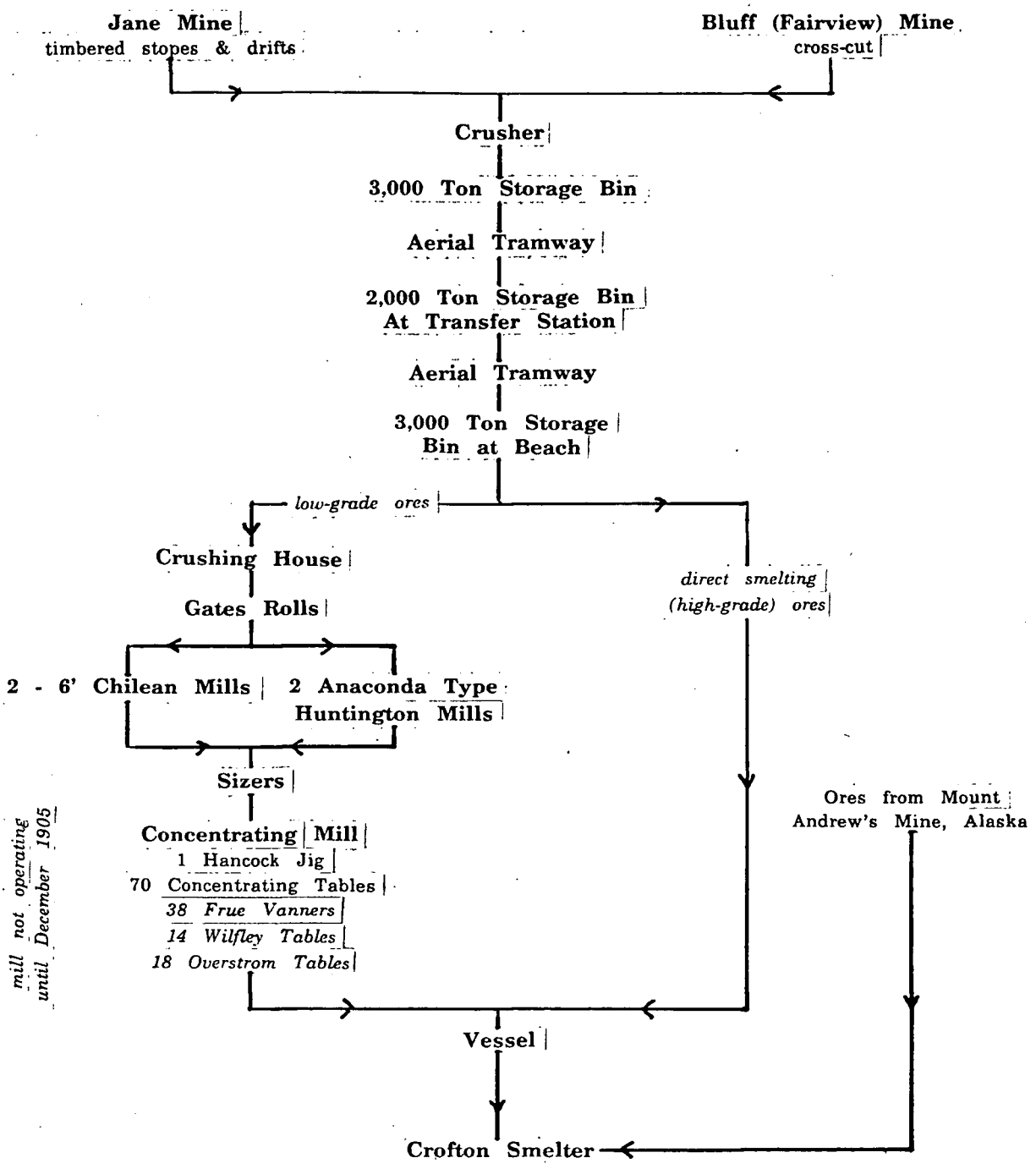
Appendix B: Flow Sheets

Figure B–1: Proposed Flow Sheet of Britannia Ores, November 1904



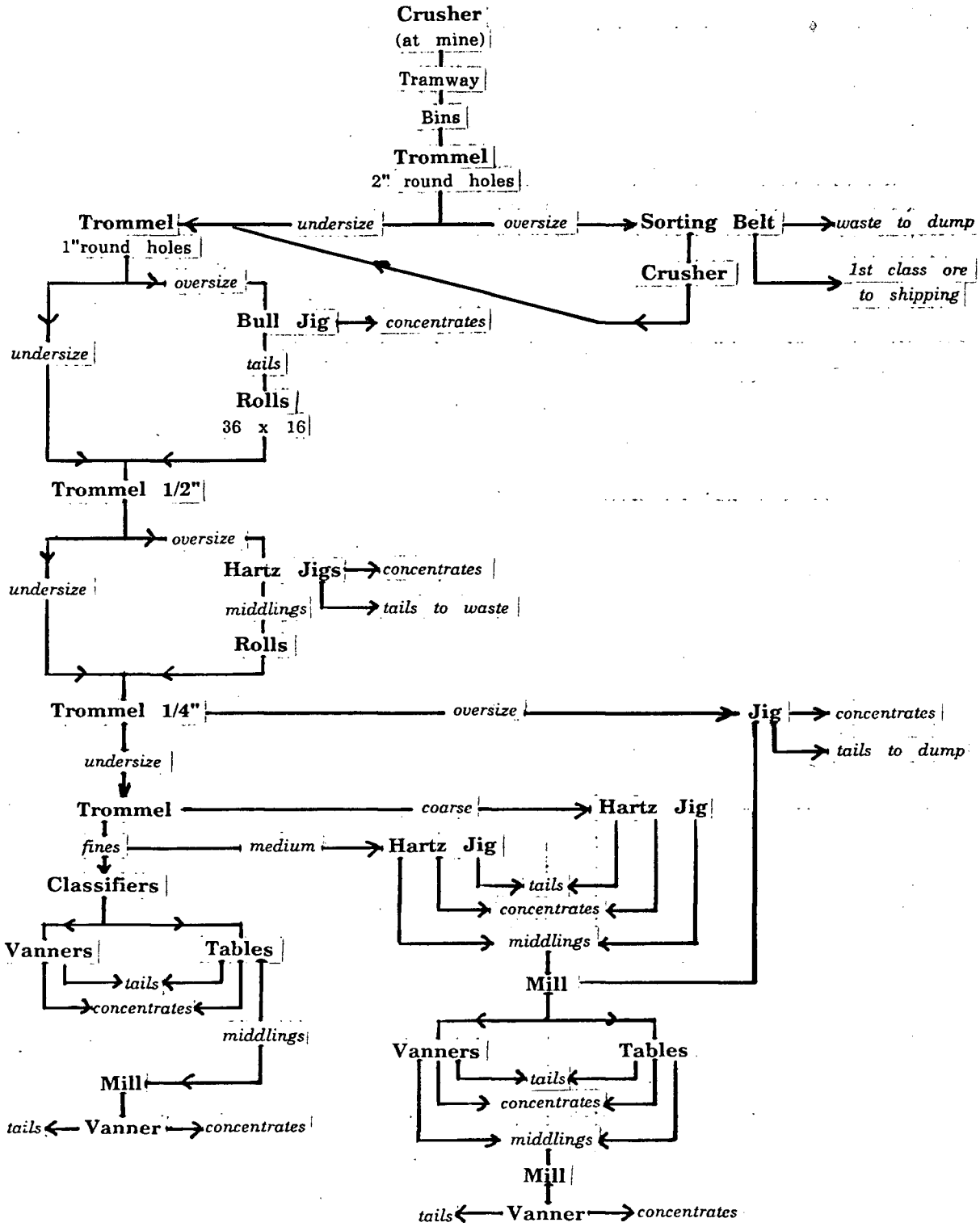
SOURCE: Derived from W. M. Brewer, "Britannia Mines, Howe Sound, B. C.," *Mining and Scientific Press* 89, 25 (December 17, 1904): 408 – 409.

Figure B-2: Flow Sheet of Britannia Ores, August 1905 - February 1906



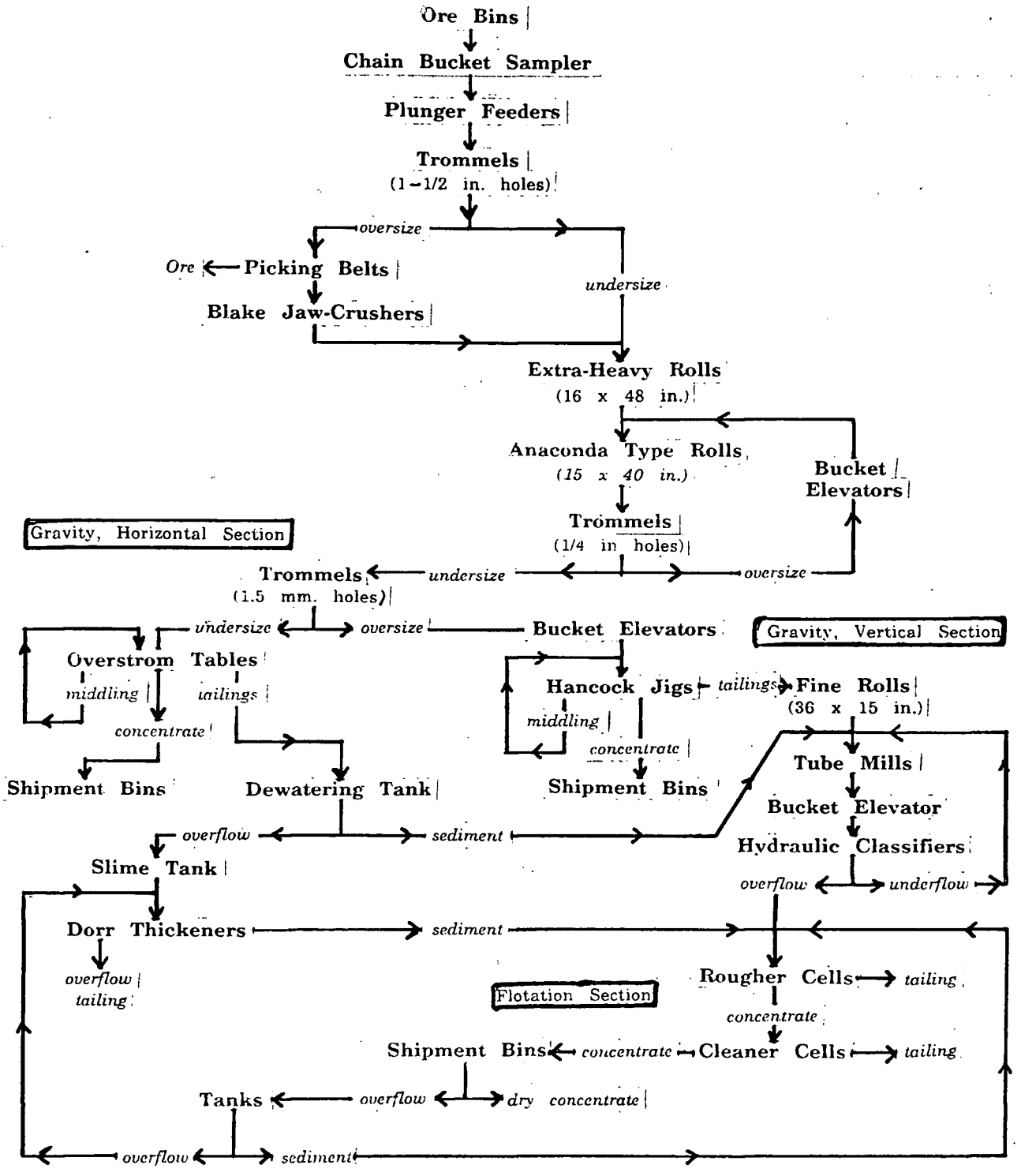
SOURCE: Derived from *Vancouver Daily Province*, September 12, 1904, p. 6; July 15, 1905, p. 1; August 4, 1905, p. 2; August 26, 1905, p. 16; August 28, 1905, p. 1; December 2, 1905, p. 5; and February 21, 1906, p. 7.

Figure B-3: Flow Sheet - No. 1 Britannia Mill, 1907 - 1908



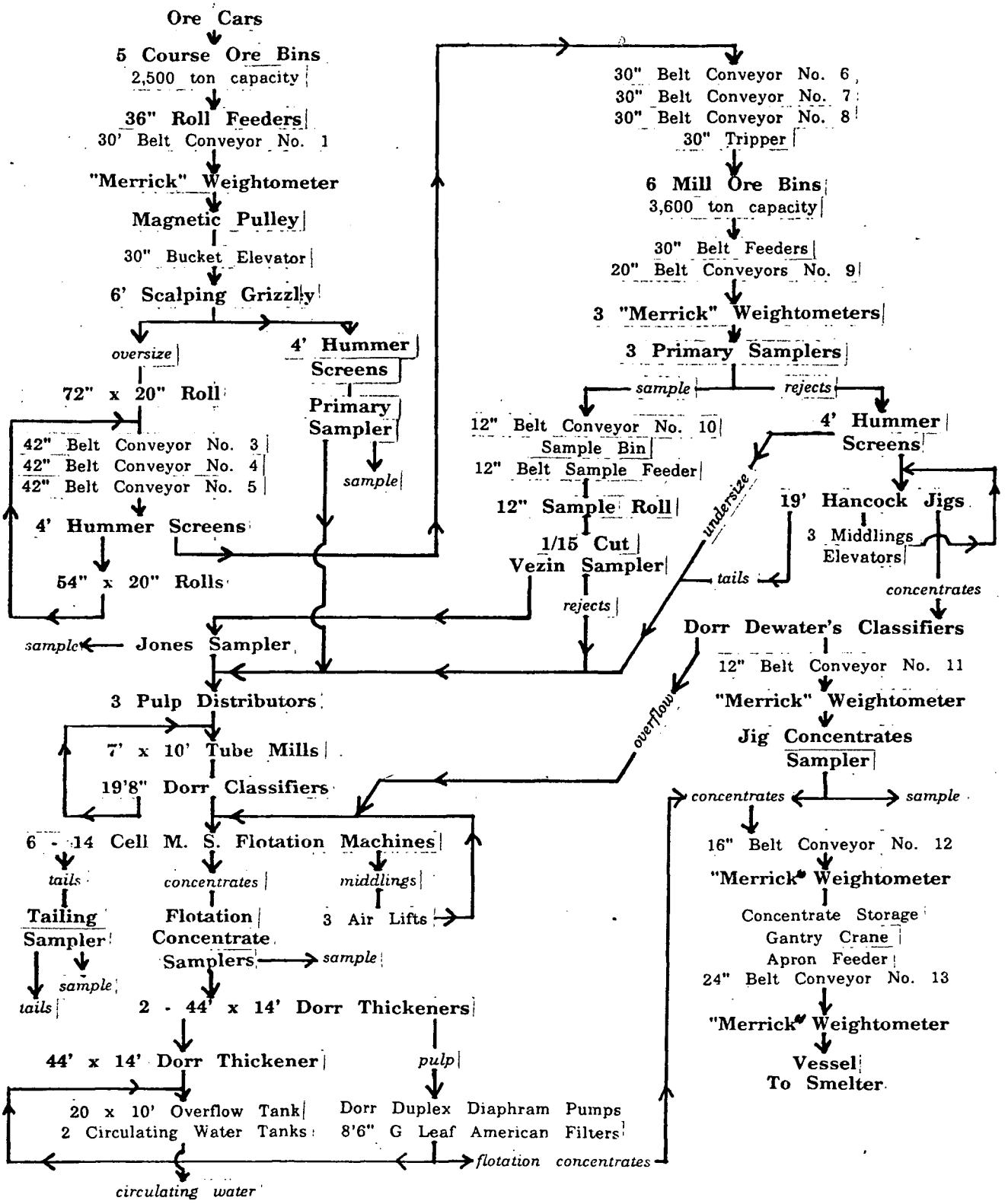
SOURCE: Derived from Canada, Department of Mines, Mines Branch, *Report on the Mining and Metallurgical Industries of Canada, 1907-8* (2 vols. Ottawa: Government Printing Bureau, 1908), I:144.

Figure B-4: Flow Sheet - No. 2 Britannia Mill, 1916



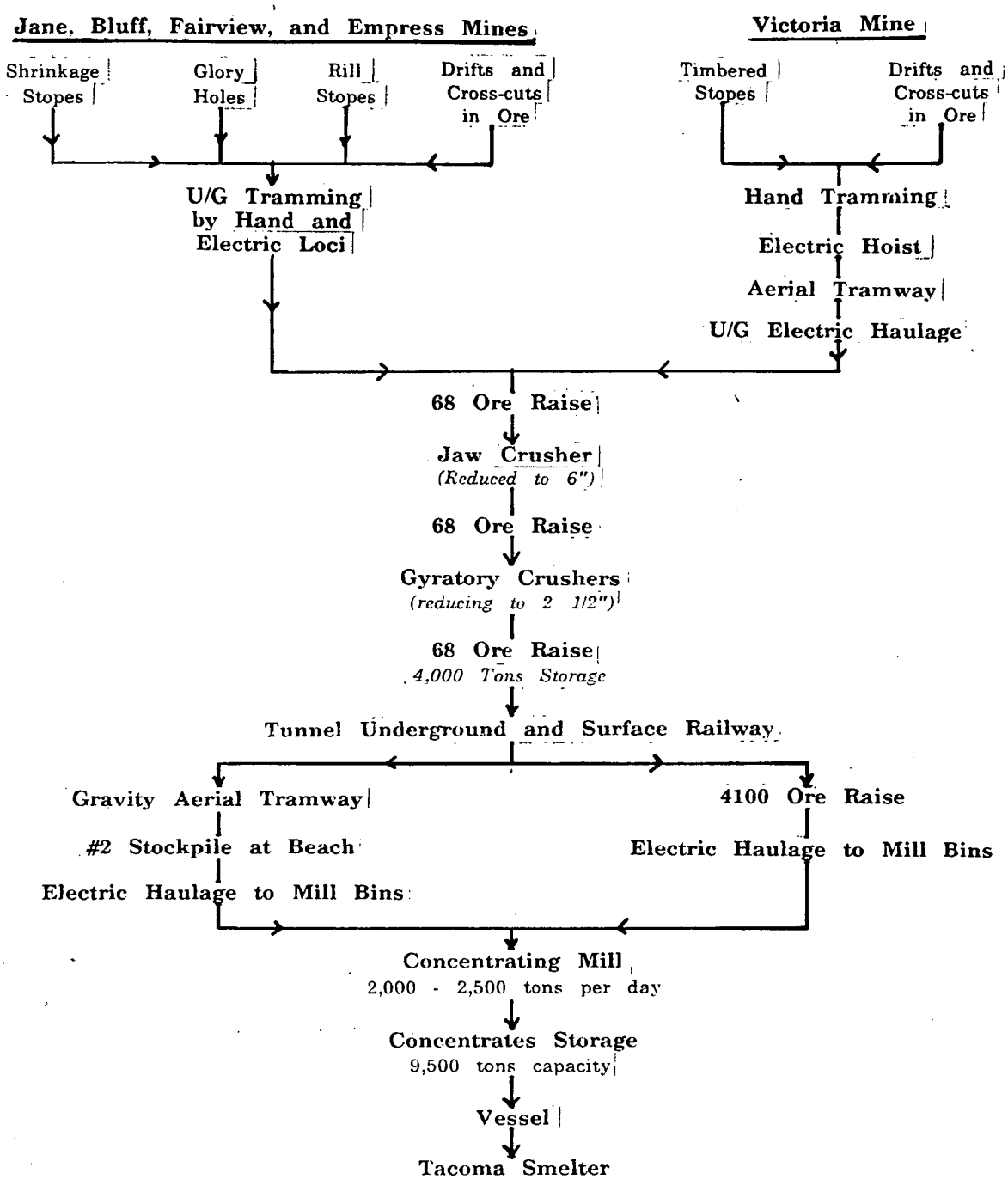
SOURCE: Derived from T. A. Rickard, "The Britannia Mine and Mill," *Mining and Scientific Press* (November 11, 1916): 697.

Figure B-5: Flow Sheet - No. 3 Britannia Mill, March 1923



SOURCE: Derived from C. P. Browning, "1922 Annual Report of Operations," PABC, Add. Mss. 1221, 1/11; and BCDOM, *Annual Report, 1922*, p. 248.

Figure B-6: Flow Sheet of Britannia Ores, March 1923



SOURCE: Derived from C. P. Browning, "1922 Annual Report of Operations," PABC, Add, Mss. 1221, 1/11, p. 4.

Appendix C:

Average Grade of Copper Ores, 1880 - 1936

Year	U. S. Mines	Britannia	Notes Re: Britannia
1880	3.00		
1889	3.32		
1899		6.0±	estimate (1)
1900		8.0±	estimate
1901		6-8	estimate
1902	2.73		
1906	2.50		
1907	2.11		
1908	2.07		
1909	1.98		
1910	1.88	4.85	in sight (2)
1911	1.82	4.04	in sight
1912	1.71	4-7	
1913	1.67		
1914	1.60	2.6±	assumed (3)
1915	1.66		
1916	1.70	2.21	Fairview (4)
1917	1.60		review (5)
1918	1.51	2.21	
1919	1.65	1.90	lowered
1920	1.63	1.90	cut-off (6)
1921	1.70	1.90	
1922	1.74	2.00	
1923	1.58	1.90	
1924	1.59		
1925	1.54	1.85	
1926	1.46	1.87	
1927	1.41	1.74	
1928	1.41	1.74	
1929	1.41	1.69	
1930	1.43	1.17	
1931	1.50	1.19	
1932	1.83		
1933	2.11	1.18	
1934	1.92	1.19	
1935	1.89		
1936	1.54		

NOTES: (1) "Estimates" based on visual assessments and casual projections over entire property. (2) "In sight" ores means that only proven ores are included in these estimates. (3) "Assumed" reflects Britannia's recognition that evaluation process was flawed. (4) For Fairview mine only: no grade estimates reported for entire property. (5) Evaluation process under review between 1916 and 1919. Reflects installation of flotation process in No. 2 Mill. (6) The review process established a systematic evaluation of all ores - proven, probable, and possible - and reflected a greater sensitiveness to production costs and the price of copper.

SOURCE: U. S. grades from Y.S. Leong, *et. al., Technology, Employment, and Output Per Man In Copper Mining,* Report No. E-12, Work Projects Administration, National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques, Philadelphia, February 1940, p. 220. Britannia grades obtained from engineering reports and the annual reports of the mine superintendent and the general manager of the Company. PABC, Add. Mss. 1221, Boxes 1, 2, and 114.

Appendix D:

Britannia Mines Production, 1905 - 1937

Year	Mined (tons)	Milled (tons)	Gold (ozs.)	Silver (ozs.)	Copper (lbs.)	Lead (lbs.)	Zinc (lbs.)
1905	17,082	13,000	409	3,529	2,631,520		
1906	88,879	53,496	2,819	4,535	2,631,520		
1907	57,374	26,730	1,643	12,397	1,881,190		
1908	17,624	10,450	343	3,379	610,446		
1909	17,226	17,226	303	1,224	214,380		
1910	26,387	26,387	252	8,877	1,739,821		
1911	118,908	106,904	11	46,120	8,684,545		
1912	193,035	168,950	0	78,857	14,334,727		
1913	234,271	215,121	89	72,300	13,167,000		
1914	240,272	227,119	213	68,515	11,841,232		
1915	220,834	213,150	398	50,306	9,058,045		
1916	441,323	404,063	792	91,905	15,957,719		
1917	662,383	662,000	980	86,925	15,780,830		
1918	730,652	730,000	3,050	93,385	17,669,445		
1919	615,300	609,951	4,350	94,870	16,629,848		
1920	710,450	704,450	6,013	90,672	16,201,266		
1921	47,385	no mill	646	7,943	1,411,376		
1922		no mill					
1923	682,511	682,511	4,874	108,964	22,158,893		
1924	810,357	864,401	4,684	125,687	26,398,539		
1925	1,032,596	994,113	8,231	137,919	27,996,190		
1926	1,187,632	1,156,470	9,995	155,908	31,734,089		
1927	1,349,586	1,349,591	10,336	174,064	34,909,175		
1928	1,661,325	1,613,931	15,277	202,345	42,117,663	1,883,902	
1929	1,983,769	1,920,339	14,290	209,940	42,951,205	1,935,189	
1930	2,215,600	2,152,647	12,600	211,170	45,188,466	616,774	
1931	2,022,321	1,968,494	5,315	143,110	28,516,604	304,714	
1932	809,259	809,259	8,868	62,470	11,732,678	1,328,900	
1933	659,440	622,718	12,819	45,044	7,991,091	1,944,091	9,374,675
1934	786,412	759,697	14,078	57,913	9,779,903	2,157,360	6,316,263
1935	817,250	817,250	13,826	71,357	14,732,691	1,484,581	3,606,436
1936	1,311,835	1,311,835	13,033	94,193	19,845,562	944,466	727,398
1937	2,116,075	2,116,075	12,018	155,740	33,064,933	900,646	0
Totals	23,885,353	23,328,324	182,555	2,771,563	574,559,264	13,500,747	20,024,772

SOURCE: BCDOM and Bureau of Economics & Statistics, "Gross Contents - Britannia," Victoria, updated annualy, BCMM-CF, history reviews file.