Western Australian Gold Smelters in the 1900s

BY RICHARD G. HARTLEY

The significance of the smelting of Kalgoorlie gold ore and concentrates in South Australia, New South Wales and Western Australia and the important role it played in the output of the Kalgoorlie mines in the years between 1897 and 1904 has been largely overlooked. Between 1897 and 1901, over 135,000 tons of mainly rich sulpho-telluride ore and concentrates were shipped to smelters outside Western Australia, from which over 580,000 ounces of gold bullion were produced.[1] These made up nearly a quarter of the total gold produced on the Kalgoorlie Golden Mile during those years. In addition, between 1901 and 1904, 145,000 ounces of bullion were produced at two successive smelters at Fremantle, and nearly 50,000 ounces at a small smelter at the Golden Horse-shoe mine in Kalgoorlie. Thus, nearly a third of the 0.8 million ounces of smelted gold bullion produced to 1904 was processed in these three smelters. All three were financed by Charles Kaufman, the controversial American mining engineer-financier, and two of Kalgoorlie's most celebrated metallurgists were associated with their design and management, John Sutherland and Charles Klug.

Hannan's Brownhill was the first mine to ship ore to smelters in the eastern colonies when in 1896 it commenced the shipment of rich oxidized and sulphide ore from the Oroya shoot, the first of the famous shoots to be discovered on the Golden Mile. Subsequently, about 90 per cent of the ore smelted from all sources consisted of sulpho-telluride ore, together with some rich oxidized ore. The remaining ten per cent consisted of concentrates separated in oxidized ore or wet sulphide ore treatment plants by blanketing tables and mechanical concentrators (predominantly Frue Vanners and Wilfley tables). Small quantities of gold room slag were also included in this ten per cent.

Altogether, sixteen Kalgoorlie mines or processing companies made shipments to smelters from Kalgoorlie, although the tonnage of ore shipped by the seven mines shown in Table 1 constituted over 95 per cent of the total. Several interesting points can be observed from the table.

- For Hannan's Brownhill in 1896 and 1897, and for Kalgurli Gold Mines in 1897 and 1898, smelting was the only form of processing carried out.

Table 1: *Ores and Concentrates Smelted 1896-1901 (selected mines) #*

Company	Years	Ore & Concentrates Smelted (tons)	Gold from smelting (oz. bullion)	Average grade – excluding concentrates (dwt per ton)	Total gold all sources (oz. bullion)	Gold from smelting % of total
Associated Gold	Pre1898	9,512	19,209	40.4	30,123	64
Mines WA	1898	3,379	17,319	102.5	41,888	41
	1899	29,869	74,522	49.9	108,270	69
	1900	(slag) 9	216		34,184	1
	1901	(slag) 16	1,208		31,524	2
Totals		42,785	112,474		245,989	46
Golden Horse-shoe Estates Co.	1899	Co 392	Co 3,857		103,573	4
	1900	C 10,024	C 27,870	50.3	132,864	21
	1901	C 22,111	C * 81,759	71.5	185,297	44
Totals		C 32,527	C 113,486		421.734	27
Great Boulder Perseverance	Pre 1898	2,008	6,960	69.3	28.078	25
GMC	1898	1,640	4,374	53.3	18,279	24
	1899	2,405	17,868	148.6	40,996	44
	1900	C 22,217	C 21,579	59.4	47,099	46
Totals		C 28,270	C 50,781		134,452	38
Hannan's Brownhill GMC	Pre 1898	5,040	30,306	120.2	30,306	100
	1898	227	1,339	117.9	50,894	3
	1899	400	3,243	162.1	90.934	4
	1900	C 1,644	C 14,228	107.5	80,757	18
Totals		C 7,311	C 49,116		252,891	19
Ivanhoe Gold Corporation	Pre 1898	112	134	24.0	43,128	
	1899	Co 3,007	Co 543		104,009	3
	1901	C 3,365	C ** 13,926	57.0	108,767	13
Totals		C 6,484	C ** 14,603		255,904	6
Kalgurli Gold s	Pre1898	1,053	4,694	89.1	4,694	100
Mines	1898	245	2,102	171.4	2,102	100
Totals		1,298	6,796	104.9	6,796	100
Lake View	Pre 1898	C 276	C 2,998	100.7	95,645	3
Consols	1898	C 175	C 2,008	85.7	98,110	2
	1899	C 10,328	C 163,599	316.8	235,773	69
	1900	2,106	41,706	396.1	98,770	42
Totals		C 12,885	C 210,311		506,902	41
Grand Totals		C 131,560	C 557,567	85.0	1,824,668	31

Other mines or plants shipping to smelters included: Brown Hill Extended; Great Boulder Pty.; Great Boulder Main Reef; Hannan's Oroya; North Boulder; North Kalgurli; South Kalgurli; King & Co.'s Smelting & Metallurgical Works.

* includes 24,643oz smelted on mine from 2,245 tons ore (237 dwt per ton).

** includes gold from 289 tons of ore and concentrates roasted in dedicated shaft furnace and treated on mine

C - includes concentrates or gold from concentrates. Co – concentrates only or gold from concentrates only.

Note: Figures are for years ending 31 December.

Sources: Department of Mines Western Australia, and Company annual reports.

- Some of the sulpho-telluride ores smelted were extremely rich. Ore shipped from the Lake View Consols mine in 1899 and 1900 was the richest ever mined in large quantities on the Golden Mile, averaging over 300 dwt per ton.
- At Lake View Consols and also at Associated Gold Mines there were large increases in the quantities of gold smelted in 1899. These increases clearly point to the role that smelting played in providing a means of substantially boosting the production of these mines over a short period.

It was no coincidence that the two mines were controlled by two of the most unscrupulous financiers then operating on the London Stock Exchange, Horatio Bottomley (Associated Gold Mines) and Whitaker Wright (Lake View Consols).[2] The very large increases in gold production that occurred in 1899 at the two mines represented unsuccessful attempts by the two men to stave off the 'bearing' of the two mining stocks by rival financiers. The boosting of production led to the rapid deterioration of these mines, which were two of the most valuable on the Golden Mile. Both mines were gutted of their most valuable ore, increasing the cost when at a later date the less valuable material was mined.

The main drawback to the early smelting of Kalgoorlie ore was that the nearest smelters were in the eastern colonies, at Wallaroo and Adelaide in South Australia, and at Dapto (near Wollongong) in New South Wales.[3] These operated as copper or silver-lead smelters, but could be adapted to deal with shipments of gold ore. Smelting was also an expensive process. Contemporary estimates gave the average all-inclusive cost of smelting ores in the east as £5. 10s per ton.[4] This meant that ore had to have an assay value of at least 26 dwt per ton for a shipment to be profitable. Another drawback was that the preparation of ore for shipping was a very labour intensive and tedious job. Ore crushed to below a three-inch maximum sizing had to be packed and sealed in 70 lb capacity canvas bags, large numbers of which were required.[5] For example, in 1899, Associated Gold Mines shipped out over 955,000 bags of ore, at an average of over 3,400 bags per working day.[6]

In 1897, Charles Kaufman, Whitaker Wright's manager in Western Australia, left Wright to work for Bottomley.[7] However, he soon also left Bottomley to pursue his own promotional schemes. In late 1897 or early 1898, he gained financial control of the Golden Horse Shoe Gold Mining Company.[8] In the following year he floated a new company, Golden Horse-shoe Estates Company Ltd., so as to take over the assets of the

old one.[9] John Sutherland, the chief metallurgist at Lake View Consols was appointed the company's general manager in August 1899. George C. Klug, a young Victorian with a mining degree from Adelaide University, was recruited from BHP where he had been chief chemist and assayer and assistant metallurgist, to become the Golden Horse-shoe's chief metallurgist.[10]

In March 1900, Kaufman formed a new company, Fremantle Smelting Works Ltd., to operate a custom smelter at Fremantle.[11] Smelting at Fremantle offered substantial savings over shipment to eastern smelters. These savings related not only to direct transportation costs but also to costs less immediately obvious, such as the avoidance of bagging ore because of availability of bulk haulage in special wagons provided by the Government, and a freight rebate on ore smelted in Western Australia.[12] A new policy was now adopted by the Golden Horse-shoe. Its standard grade sulphide ore and concentrates were to be sent to Fremantle for smelting, and a small smelter was to be built at the mine to deal with the mine's high grade sulpho-telluride ore.

The decision to build a small smelter on the mine no doubt had the support of Sutherland but he would have been less enthusiastic about the decision to smelt ordinary grade sulphide ore at Fremantle.[13] Smelting at Fremantle would adversely affect the profitability of the mine as it would be more expensive than treating the ore at the mine by roasting and cyaniding, the procedure being adopted by most of the neighbouring mines. It is not difficult to see the directing hand of Kaufman behind this new policy. Sutherland's support for the Fremantle smelter was, in the end, guaranteed by making him general manager of Fremantle Smelting Works.[14]

The Golden Horse-shoe Smelting Works

The small smelting works, which commenced operations on the Golden Horse-shoe mine in 1900, was the most advanced processing plant yet built on the Golden Mile. Klug and Sutherland appear to have been fully responsible for its design and commissioning without any input from specialist consultants.[15] Kaufman was also astute enough to realise that there were other advantages to be gained from operating a smelter at the mine. In particular, Klug gained valuable experience from the smelter, which he was able to make good use of in his design and commissioning of a full-scale smelter at Fremantle for another of Kaufman's companies in 1903.

The Golden Horse-shoe's smelter produced high-grade bullion in three stages.[16] The first was a small water-jacketed blast furnace, similar to the type of copper furnace

used in Colorado from the 1890s.[17] It was made by Martin and Co. of Gawler in South Australia, and had a capacity of 30 tons of ore and flux per day, of which from eight to ten tons consisted of the ore to be treated. The fluxing materials used were ironstone (obtained locally), limestone (from Southern Cross), and silver-lead ore from Broken Hill. Scrap iron was also added to the charge, to act as a desulphurising agent. The furnace was fired by producer gas formed from 90 per cent coke from New South Wales, and ten per cent coal from the recently discovered Western Australian deposits at Collie. In the furnace reaction, a molten gold and silver bearing lead bullion was formed, which was tapped off and further refined in the second stage that consisted of two cupellation furnaces (also made by Martin and Co.). In the final stage, the silver was removed from the bullion by a Miller's chlorination plant. [18]

During 1901, over 26,000 oz of bullion were produced from high-grade sulphide ore averaging 237 dwt per ton.[19] In the following year, some even more valuable sulpho-telluride deposits were opened up and over 23,000 oz were produced by the smelter, at a very high average of 320 dwt per ton.[20] During 1903, however, the amount of very high grade ore mined began to diminish, and at the mine a sulphide ore treatment plant was opened that was capable of processing ore more economically than the smelter, which was closed down. Costs of smelting were probably high due to the importation of all the raw materials and because of the small size of the plant. Once the mine's sulphide plant was operating effectively, there would appear to have been little justification for shipping ore to the Fremantle smelter or for smelting on site.

Fremantle Smelting Works

The first plans for the establishment of a smelter at Fremantle were proposed in 1897, when large quantities of ore first began to be shipped from Kalgoorlie to smelters outside Western Australia. There were two rival schemes, one put forward by Zebina Lane and the other by George Brookman.[21] After Brookman floated a company, Western Australian Smelting Company Ltd., in London, in October 1897, Lane dropped out of the race.[22] Brookman's promotional company, Brookman's Gold Exploration and Finance Association of Western Australia, had already leased a site for the smelting works at Rocky Bay, north of Fremantle, and had acquired lead mines in Northampton, and ironstone deposits in the Avon Valley, to supply smelting flux materials.[23]

The proposal to site the smelter at Rocky Bay, where the North Fremantle peninsula is at its narrowest, opposite what is now Leighton Beach, caused some

controversy. 'Some of the inhabitants in the vicinity' feared that fumes from the smelter 'would have a disastrous effect upon the surrounding vegetation'.[24] Eventually an alternative site at Owen Anchorage, South Fremantle was preferred as the site for the smelter, which was just as well for the people of the up-market Peppermint Grove.[25]

The Fremantle smelter commenced operation in August 1900, but by that time it was no longer under the control of the Western Australian Smelting Co., for it had been taken over by Kaufman's company, the Fremantle Smelting Works.[26] Fremantle Smelting Works also took over a contract made by the old company to purchase lead concentrates from the Broken Hill Block 10 Co.. Presumably, the Brookman company had intended to use the concentrate as charge material for the smelter.[27] It was an unfortunate legacy, which largely contributed to a loss of £86,000 made by the company in its first year. As general manager, Sutherland would have supervised the smelter's start-up and early operation, but during the first half of 1901, George Klug appears to have taken over its management [28]and remained in charge until July 1902, when the company went into liquidation.[29]

The smelter bought gold ore from the mines at between 92 and 96 per cent of the ore's assay value, at a rate of £4 per fine ounce, which was a similar rate to that paid by smelters in the eastern states.[30] Treatment charges varied according to the nature of the ore and its chemical composition, but for sulphide ore the charge was in the order of 50 shillings per ton.[31] The all-inclusive cost of treating ore from the Golden Horse-shoe, for example, was £3 .13s .3d per ton which compared favourably with the estimated cost of smelting in the east of £5 .10s per ton.[32] As the cost was around 30 shillings per ton for treating sulphide ore by roasting and cyaniding at the mine site, smelting was still not a cheap option. However, at that stage, sulphide treatment on the mines was still very unreliable. The reason for the smelter's failure in 1902, was not lack of customers but was more likely to have been due to a number of causes: technical problems with the smelter causing unacceptable increases in costs; probably a lack of liquidity due to the legacy of the lead contract; the need to provide part-payment in advance for the ore purchased; and insufficient working capital being provided by the promoters.

Despite the fate of the first smelter company, another, Fremantle Smelter Ltd., was formed in February 1903 to take over the previous company's 'properties, smelting works and assets', which it purchased for £41,000 in cash.[33] Although Kaufman was not on the board of the new company, he was clearly closely connected with it. The

chairman was E. Protheroe Jones, who had become secretary of Golden Horse-shoe Estates in 1901, and both companies shared the same London office.[34] Klug was recalled from Melbourne to become general manager of the smelter[35] and then built a completely new smelting works that commenced operation in November 1903.[36]

Klug's smelter operated on different principles to the Golden Horse-shoe Estate's small smelter. The much larger Fremantle smelter works consisting of several similar parallel units each consisting of a roasting furnace, followed by a Bessemer-style converter.[37] The furnace was charged with the gold ore or gold concentrates, lead concentrates and limestone (plus iron-ore if required). The charge was roasted without becoming molten or completely desulphurised. It was then discharged from the furnace and trucked to the converter where a current of air was blown through it to complete the desulphurisation. The lead bullion was then refined by standard methods. The furnace was described as a revolving bed furnace,[38] which sounds as if it was a Brunton cylindrical furnace, at the time commonly used at copper smelters in the USA.

As with the blast furnace at the Golden Horse-shoe's smelter, the Bessemer-style converters Klug adopted at Fremantle were 'state of the art' technology for copper smelting. The Bessemer converter was invented by Henry Bessemer for use in the manufacture of steel in 1855, but it was not until 1881 that the Frenchman, Paul David, managed to adapt it successfully to the treatment of copper concentrates, and the first copper converters in the USA were built at Butte, Montana, in 1884.[39] Subsequently they were used extensively in the USA and France, and also in Tasmania, but the Fremantle converters were probably among the first to be used on the Australian mainland. Emissions from the main chimney which served both roasters and converters, consisting of sulphur gases, oxides and carbonate of lead, and at times arsenious oxide, all unpleasant and hazardous to the small number of people living within its fallout zone. Workers on the tapping floor of the converters had a more dangerous exposure to lead and sulphur fumes, particularly when an easterly wind was blowing, the plant having been designed to make best use of the westerly sea breeze for dispersing fumes from the works.[40]

In the three years after the first Fremantle smelter was started up there were important changes in the Kalgoorlie treatment plants and in the grade of ore being mined. These changes had substantially reduced the number of potential customers for a smelter. Oxidised ore had largely been mined out, and with it had disappeared the need to treat concentrates from oxidised ore. All the major mines, including the Golden

Horse-shoe, had, by 1903, opened sulphide ore treatment plants. The discovery of rich pockets of telluride ore had become rarer, and these richer ores could in any case now be treated along with the other sulphide ores. The quantity of concentrates from sulphide ore treatment plants available for smelting in 1903 had also diminished considerably since 1901, as mines with wet sulphide plants had developed roasting plants to treat their concentrates at the mine.[41] Moreover, during the 13 months from July 1902 to November 1903, no smelting was done at Fremantle and mines that had had materials treated by the first smelter found alternative means of treating them in Kalgoorlie, probably a cheaper proposition than shipping them to the smelter.

Thus, the prospect of the Fremantle smelter attracting significant quantities of material for smelting from the Kalgoorlie mines in 1903 seems to have been remote, even if the Golden Horse-shoe had diverted some of its sulphide ore to the smelter in addition to sending its concentrates there. However, by this time, Kaufman appears to have been more interested in using the smelter for treating copper ore from the Northampton mines and from other deposits discovered more recently on the goldfields, than for treating gold ore from Kalgoorlie, as world copper prices were steadily rising.[42] In 1903 he visited copper-gold mining prospects in the Phillips River Mining District, around what is now Ravensthorpe, 330 kilometres south west of Kalgoorlie.[43] He later took an option on eleven leases in the district and commenced mining in 1906.[44] Ironically, the Fremantle smelter was never used to smelt ore from Kaufman's Ravensthorpe mines, for he purchased a copper smelter in 1906 which had been built by the Government (largely in accordance with advice given by Klug), just east of Ravensthorpe, and this was far more economical to use for local ores than the Fremantle smelter.[45]

From 1906, as the demand for lead from the European armaments industries increased, Fremantle Smelter Ltd. reorientated its operations to concentrate on lead smelting and the development of its Northampton lead mines.

Endnotes

[1] Figures are from Table 1 with allowances for smaller shipments by other companies. Figures refer to calendar years. It should be noted that Mines Department figures are for calendar years, but company figures are for financial years. Of the companies in Table 1, Boulder Perseverance, Golden Horse-shoe, Ivanhoe, and Brownhill had financial years ending 31 December, but the others differed- Lake View - 31 August, Kalgurli - 31 July, Associated - 31 March. Charleton, *Gold Mining and Milling in Western Australia with Notes upon Telleride Treatment, Costs, and Mining Practice in Other Fields*, London,

1903, table XII, gives figures for ore smelted, but these are unreliable, as the table mixes figures for annual and financial years, and makes several incorrect allowances for concentrates. It should be noted that figures in Mines Department annual reports relate to bullion ounces (gold plus silver) before 1903 and to fine ounces (gold only) after 1903. Previous researchers using Mines Department data have overlooked this important point.

[2] For Wright and Bottomley's financial dealings in Western Australian mining companies see: R.T. Appleyard & M. Davies, 'Financiers of Western Australia's Goldfields' in R.T. Appleyard & C.B. Schedvin (eds), *Australian Financiers: Biographical Essays*, Melbourne, 1985, pp. 241-48, 254-55; T. Sykes, *Two Centuries of Panic*, Sydney, 1988, pp. 200-23, 566-67.

[3] These were the locations of the Australian smelters to which Kalgoorlie mines are known to have shipped consignments for smelting. Only rarely did company annual reports specify where smelting took place.

[4] Charleton, *Gold Mining and Milling,* pp. 295-96.

[5] *Ibid.*

[6] Tonnage from Table 1. Average based on 5.5 working days per week less public holidays.

[7] Richard Hamilton credited Kaufman with being responsible for acquiring Ivanhoe Gold Mining Co. for Wright's London and Globe Finance Corporation. The latter then promoted a new company, Ivanhoe Gold Corporation Ltd. registered in London on 14 October 1897. Kaufman probably joined Bottomley shortly after this. 7 July 1897, Hamilton letter to Lane. Letter Book no. 1 of Richard Hamilton, General Manager of Great Boulder Pty. (1896-1927), [hereafter Hamilton LB 1], p. 89.

[8] On 22 July 1897, Hamilton LB 1, p.95, Hamilton wrote to Lane saying that he was anxious to settle a dispute with the Horse Shoe mine, as he expected the manager (Dick) would be dismissed now that Kaufman had control of the company. Kaufman's position appears to have become less dominant after he joined Bottomley and he probably lost heavily on Bottomley's companies. 6 May 1898, Hamilton LB 1, p. 411, Hamilton wrote to Waddington stating, 'I am wondering whether he [Kaufman] has been hit by Bottomley's fall'.

[9] *Mining Manual,* 1897, p. 148, *Ibid.,* 1899, pp. 113-14, *Ibid.,* 1900, pp. 103-04. Four of the seven directors of the old company became directors of the new, including Kaufman. For the old company, the spelling was 'Horse Shoe', and for the new 'Horse-shoe'.

[10] J. Sutherland in 'Manager's Report', Golden Horse-shoe Estates Co. First Annual Report1899. *Proceedings Australasian Institute of Mining and Metallurgy*, October 1935, Klug obituary.

[11] *The Mining Manual,* 1900, pp. 92-93. Three of the four directors of Fremantle Smelting Works were also directors of Golden Horse-shoe Estates.

[12] Charleton, *Gold Mining and Milling,* pp. 296-97.

[13] At the second annual meeting of Golden Horse-shoe Estates, in April 1900, it was announced that the smelting plant and the refining equipment to go with it had already been ordered. It seems likely that the decision on the small smelter was made before the end of 1899.

[14] *The Mining Manual,* 1902, p. 86.

[15] Klug probably had the greater responsibility for commissioning the mine smelter because for much of 1900 Sutherland would have been closely involved with commissioning the Fremantle smelter which commenced operation in August, as he was its general manager.

[16] R. Allen, 'Description of the Ore Reduction Plant and Process of Reduction on the Golden Horse-shoe Mine', *Monthly Journal of the Chamber of Mines of Western Australia,* 5, 1906, pp. 322-32. Photographs of the blast furnace and cupellation furnaces are in Charleton, *Gold Mining and Milling,* pp. 404-05.

[17] For a detailed history of the development of copper smelters (the type used for gold smelting) see W. Gowland (Professor of Metallurgy at the Royal School of Mines), Presidential Address, *Transactions Institution of Mining & Metallurgy*, 16, 1906-7, pp. 265-95. In the first half of the nineteenth century, the two main centres, South Wales and Germany, developed different technologies, the blast furnace in Germany and the reverberatory furnace in Wales. Large-scale furnaces of both types were developed in the USA from the 1890s. In the reverberatory furnace the charge and fuel were not mixed. The furnace roof was heated by flames drawn through the furnace and the heat was radiated down onto the charge from the roof (hence the term reverberatory). This type of furnace was also widely used for roasting (calcining) sulphide ores, and all the roasters used in Kalgoorlie were reverberatory furnaces.

[18] In the cupellation furnaces, the lead bullion, in refractory dishes (or cupels), was oxidised under a blast of hot air. The lead monoxide formed was reused in the smelter. See Allen, 'Reduction Plants and Processes', p. 164. In the chlorination plant (invented by Miller at the Sydney Mint in 1867) chlorine was passed through molten bullion to remove the silver as a chloride scoria. See J.E. Clennell, *The Cyanide Handbook*, New York, 2nd ed., 1915, p. 332.

[19] Department of Mines, 1901 Annual Report.

[20] Golden Horse-shoe Estates, 1902 Annual Report.
[21] Knowledge of Lane's plans comes through Hamilton's letters. Hamilton had been manager of a copper mine and smelter in Arizona from 1893 to 1895 and retained contacts in the USA, one of whom he recommended to Lane as metallurgist for the Fremantle smelter. 1 September 1897, Hamilton to W. Kemp, Silver City, New Mexico, LB 1, p.156.
[22] Noted in a further letter 28 December 1897**,** Hamilton to Kemp, LB 1, p. 207.
[23] *The Mining Manual* 1899, p. 331.
[24] E.S. Simpson, 'Fumes from Fremantle Smelting Works', *Annual Progress Report of the Geological Survey for the Year 1897*, pp. 43-44.
[25] *The Mining Manual* 1899, p. 331.
[26]*The Mining Manual* 1900. pp. 92-93. August 1900 is assumed to be the probable start-up date because Charleton, *Gold Mining and Milling*, p. 297 notes that in the last five months of 1900, 9,437 tons of sulphide ore from the Golden Horse-shoe mine were smelted at Fremantle. The Fremantle Smelting Works Ltd. was registered on 29 March 1900.
[27] *The Mining Manual* 1902, p. 86.
[28] M.K. Quartermaine, 'George C. Klug', unpublished short biography, circa 1982, p. 1.
[29] *The Mining Manual* 1903, p. 76.
[30] Charleton, *Gold Mining and Milling*, p. 296.
[31] *Ibid.*
[32] *Ibid.,* p. 295.
[33] *The Mining Manual* 1904, p. 77.
[34] *Ibid.,* 1900, p. 104; *Ibid.,* 1903, p. 83; *Ibid.,* 1904, pp. 77, 84.
[35] M.K. Quartermaine, 'George C. Klug', p. 1.
[36] *The Mining Manual* 1904, p. 77.
[37] Smelter details from: 'Report of the Royal Commission on the Ventilation and Sanitation of Mines', *Votes and Proceedings of the Parliament of Western Australia,* 1905, vol. 1, paper A6, section 44, pp. 42-43.
[38] *Ibid*., p.42.
[39] Gowland, *Transactions Institution of Mining & Metallurgy,* 16, 1906–07, p. 287.
[40] 'Report of the Royal Commission on the Ventilation and Sanitation of Mines', p. 43.
[41] Lake View Consols 1901-02 Annual Report.
[42] Commercial exploitation of the three major copper deposits in Western Australia at Ravensthorpe, Murrin Murrin (Mt. Margaret GF), and Whim Creek (W. Pilbara GF), began during this period.
[43] M.K. Quartermaine, 'Some Aspects of Mining at Ravensthorpe', *Proceedings Royal Western Australian Historical Society,* 9, 1984, part 2, p. 110.
[44] *Ibid*., pp. 110-111, states that Kaufman formed the Phillips River Gold and Copper Co. Ltd. in January 1906 and appointed Klug its first manager (1906-1908).
[45] *Ibid.,* p. 111.