

Balanced costs: Inland copper smelting location and fuel in South Australia 1848-76: Were they so naïve?

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Because it takes more than one ton of coal¹ to smelt a similar quantity of minerals, and because coal is weight for weight less valuable than the mineral, it makes good logistical and economic sense to transport the mineral to the coal rather than *vice versa*. Yet in the 19th century at the Burra Burra mines, common sense appears to have been turned on its head. Not only was the smelter erected by the Patent Copper Company (later called the English & Australian Copper Company) located in South Australia, where at the time there were no proven coal deposits, but it was situated at Kooringa 160km inland from the main Port of Adelaide, and adjacent to the Burra Burra mines, thus making the decision seemingly even more illogical from an economic point of view. The paper sets out to examine the reasoning behind the decision to locate at the site.

Early Smelting

The decision to smelt ores locally was undertaken by the proprietors of the South Australian Mining Association [SAMA] in the belief that it would increase profits, as it was believed that the value-added would mean greater unit returns, lead to transport savings associated with reduction of the ores (especially low grade ores), and remove the company from reliance upon the Swansea (UK) smelting oligopsony that controlled most of the world's smelting activity.

The alternatives considered were whether to smelt near the mine, or to choose a site near the coast, or to take the ores to a site in proximity to coal reserves. Of the latter, Tasmania was one option considered, while another obvious location was identified as Newcastle, NSW. The editor of New South Wales' *Maitland Mercury*, had no doubts about the best location, seeing Newcastle as being 'admirably adapted for carrying on the smelting trade' for South Australia, having advantage of cheap coals, and good harbour facilities.² Similar arguments, plus the advantage of cheap convict labour were later extended to locating at Schouten Island, Tasmania.³ However, such argument did not sway the majority of mine directors who quickly calculated that the supposed advantages were illusory and that they would be better off shipping and selling their ores in Swansea than risking their subterranean wealth on untried utopias. Even more beneficial than Swansea was the perceived advantage in locating next to the mine using charcoal as the fuel for smelting. This advantage was detailed in the *Mining Journal*, it being claimed that the Burra miners would produce copper at half the cost when compared to sending to Newcastle or Swansea. This was based on a calculation that that concluded the benefits of using charcoal would substantially outweigh the freight costs for ores despite the fact that for smelting purposes, three-times the weight of charcoal would be required than coal and that per ton, charcoal was almost twice as expensive.⁴ This was the conclusion despite the calculation being biased in favour of the two outports, for the *Mining Journal* ignored the cost of sending the ores to Port Adelaide. It also ignored the transport advantages to the miners of reducing ores to copper close to the mine that would have resulted in greatly cutting transport costs to that Port. The basis of the original calculation was no doubt based on SAMA

undertaking the smelting its own ores, something that it attempted with some alacrity soon after the opening of the Burra mine.⁵

The main reason for this decision was probably associated with the abundance of wood, especially hardwoods, reported as burning with 'an intense heat and steady blaze ... [which made a] most superior charcoal'⁶ These hardwoods were believed to be in such profusion in the area surrounding Burra that early smelters forecast being able to supply all fuel wants for at least 30 years,⁷ thus making the movement of ores to the coalfield unnecessary.⁸ This was recognized even before the first charge was fired at the opening of the Burra Mine on 29 September 1845, for a week earlier, director, James Bunce, reported that a newly arrived group of German miners and smelters were prepared to process SAMAs ores if allowed a proportion of all copper produced.⁹ Subsequently a Captain Eÿ and Captain George Ludwig Dreyer and his son were appointed to supervise construction of a charcoal furnace.¹⁰ Capital outlay promising to be small, SAMA agreed to supply the materials, with smelting utensils and tools being purchased from the German smelters for £120 15s, bricks being supplied by contractor John Bagg using clay found on SAMA land at £1.7s per 1,000, and timbering of the smelter house amounting to £265.¹¹ With a contract for a Mr Breeze to supply 1,000 bushels of charcoal at seven pence a bushel delivered to the Mine,¹² the directors sat back to await early results but hope turned to frustration as delay followed delay. Language and communication problems between SAMA personnel and Eÿ and Dreyer that necessitated the appointment of F.V. Sommers as interpreter, a shortage of skilled artisans, especially masons, deficient knowledge of design and use of inferior materials by smelting-house architect and SAMA director, G.S. Kingston, were just some of the problems encountered.¹³

It took 19-months, until April 1847, rather than the anticipated few weeks, before the smelting house was completed and until September of that year before the first trial took place.¹⁴ It produced four cwt of copper at the first smelt but the performance was unsatisfactory due to mechanical deficiencies and high production costs.¹⁵ Dreyer became the scapegoat for the disappointing performance, being declared a 'good smelter ... [but] too fond of having a host of Germans about him, some of whom are merely loungers about, and not particularly zealous in the cause'.¹⁶ This experience saw the directors abandon all efforts to smelt on their own account. With the furnaces estimated as only being able to produce eight cwt of coarse copper per day, and with the ambition to pass through large tonnages, the directors realized that much larger sums would have to be outlaid in order to capitalise a satisfactory smelter.¹⁷

Even before this, other outlets were being investigated. By July 1846, doubts as to the progress were evident, for Dr. Edward Davy,¹⁸ who had unsuccessfully asked the directors in December 1845 to accept his own smelting process, was approached to see whether he would undertake the venture, the directors being impressed by the claim that his process was capable of producing one ton of copper from five tons of 20 per cent ore, using only 165 bushels of charcoal.¹⁹ Despite a satisfactory trial attended by SAMA directors, that produced 23lbs of 'pure copper' from 44lbs of ore,²⁰ the terms offered by Davy were unsatisfactory.²¹ Davy also suffered from a shortage of capital and a month after his first overtures, SAMAs Board was again approached, this time to persuade them to take out shares in a smelter that his Adelaide Smelting Company was constructing at Yatala, near Port Adelaide - but again he was turned down.²² This rejection was not explained, though it can be surmised that SAMAs directors were not convinced that he could handle the large tonnages that they envisaged and were also concerned at the difficulties he would meet in finding sufficient charcoal fuel for his project. Davy had planned to obtain his wood from areas surrounding Adelaide,

Kangaroo Island and the Yorke Peninsula²³ but with the proliferation of farming close to the City, the requirements of timber and fuel by a growing population and the fact that much land had already been taken into private hands, then the cost of wood (if obtainable), promised to be prohibitive, especially when compared to the resources on SAMAs own 10,000 acre survey and the timber available from the adjacent Murray Scrub. Davy had earlier reported that to provide charcoal to produce three tons of copper a day would require two acres of land and that it would take six tons of charcoal to reduce 15 tons of ore.²⁴ The doubts of SAMA were further strengthened when Davy's company failed to pay SAMA for ores received, resulting in litigation from the end of 1849 that wasn't resolved until some four years later.²⁵

But SAMA also had other options. In January 1849, Charles Morrissey Penny and William Owen²⁶ opened their 'Apoinga' smelter some 37km south of Burra and situated in the midst of a plentiful supply of timber.²⁷ Some two years earlier, in October 1847, they had approached SAMA to obtain a monopoly,²⁸ claiming they could treat ores containing as little as five per cent copper.²⁹ The directors declined but allowed them 5,000 tons of ore on the understanding that payment should be in copper or cash, with security to be provided as ore was delivered.³⁰ Results were far from satisfactory. SAMAs Directors Minutes show that only about two-thirds of the 5,000 tons had been smelted by 17 July 1851, and that because of small capacity, the proprietors had continually failed to remove tonnages of ore set aside for them by SAMA.³¹ In addition, the furnaces, according to Annear and Bannear, could smelt only very high-grade ores.³² Furthermore the quality of the copper produced being suspect, SAMA insisted in 1850 that the firm should pay for ore in cash³³ at a rate of 10 shillings per unit.³⁴ Small tonnages continued to be supplied until a few months before the effects of the goldrush temporarily closed the Apoinga establishment but SAMAs directors had long before seen little chance of economic salvation in that direction.

Patent Copper Company and the English & Australian Copper Company

It was early realized that Burra ores were 'exceptional', for unlike nine-tenths of copper found in the world at the time, that were sulphurets, the mine produced hydrated carbons and oxides.³⁵ This had both an up and a down side. On the up side was that the ores did not require concentration or calcining, though this was partly offset by the need to hand dress before smelting, whereas sulphurets could be placed directly into the furnace with little or no preparation.³⁶ On the down side might be considered the fact that the ores of hydrated carbons and oxides did not enjoy the advantages of sulphurets which were naturally combustible because of the sulphur content,³⁷ although that seeming disadvantage was more than compensated by other advantages. Thus, in Swansea, the smelters were delighted at the high quality of the Burra ores which when mixed with sulphurets enabled eight processes to be reduced to six thus reducing costs.³⁸ But even better was the benefit promised to the SAMA board by the overtures of a Swansea based Company, the Patent Copper Company [PCC] owned by Henry William and John Schneider. The company claimed that their 'Napier' process offered the solution to SAMAs woes by reducing the number of processes from eight to two,³⁹ with significant savings in time and fuel.

Located at the Spitty Works, Loughor [Llwchwr], in South Wales, the Schneider Brothers had experience of mining, and smelting, including in South America, before purchasing the Spitty property in 1845. Adopting the Napier process, they were noted as purchasers of SAMAs rich produce, but rather than compete at the Swansea ticketings for these much vaunted ores, they decided to persuade the Association to grant them a monopoly on ore purchases and to open up a smelter in South Australia. Their idea was

to send the richer ores to the Spitty smelter while smelting lower grade ores in the Colony. Surprisingly, without any guarantee from the Mining Association, the PCC decided to establish a works in South Australia, sending out their representative Gregory Seal Walters⁴⁰ in October 1848, on the basis that he would be able to negotiate a favourable deal with the Burra miners.⁴¹ In early negotiations, SAMA offered Walters the same opportunity to tender for ores as it did to other local purchasers but promised special privileges if his Company agreed to erect their smelter at Kooringa rather than at Port Adelaide.⁴² Under this inducement, a contract was subsequently signed on 20 November 1848 to smelt SAMAs ores for a period of seven years.⁴³ This decision wasn't without its opponents, for a minority among SAMAs directors, fighting for personal vested interests in Davy's Adelaide Smelting Company, vehemently opposed the contract on the grounds that it was '... inexpedient to contract to deliver so large a proportion of the produce of the Burra Mine for one party while such other processes are untried'. They further argued that if the PCC had so superior a process then it need have no fear of competition from other bodies and would be able to maintain its monopoly in the free market.⁴⁴ The protest when considered at the Annual General Meeting was defeated by 22 votes to four,⁴⁵ enabling the PCC to almost immediately transport inland the equipment and personnel it had already optimistically shipped from Wales to construct and man the works. On 11 December 1848, the foundation stone of the new enterprise was laid⁴⁶ and by 1850 over £60,000⁴⁷ had been expended on plant alone. By September 1853 when the Company was taken over by the English & Australian Copper Co. [E&ACC], total South Australian assets amounted to £203,000.⁴⁸ The Company was located at an 80-acre site they named Llychwr, adjacent to the mine that was let at peppercorn rent to the PCC by SAMA. The first furnace of six already completed, was ceremoniously fired by the Bishop of Adelaide on 31st March 1849 – an amazing feat when considered that accommodation for the workers, a brickworks and other infrastructure had all been constructed in 15 months at a site set over 150km inland from Adelaide.

No doubt delighted at the expeditious way that construction had taken place, the smelters must soon have had misgivings at the haste in which they had finalized the contract, for rather than being granted a monopoly on ores, the 'special consideration' merely gave them the right to acquire all ores below 35 per cent, with returns being based on a sliding scale up to that percentage. Thus, for ores of 10 per cent the smelters were bound to repay SAMA with 45 per cent of the copper produced. For 35 per cent ores the return to SAMA amounted to 75 per cent of the copper. Above 35 per cent SAMA could use its own discretion on whether to sell to the PCC or any other South Australian smelter, or to send to Swansea.⁴⁹ It is no wonder that SAMAs Secretary, Henry Ayers, could triumphantly inform the Association's major shareholder that 'We have made a capital arrangement with Schneiders people'.⁵⁰ The extent of the PCCs misgivings must, however, have soon come home to Walters who had believed the agreement related to the percentage when brought to 'grass', when in fact SAMA related the agreement to dressed ores. When the prolific water pumped from the mine allowed for more efficient dressing of the ores, this allowed SAMA to cheaply raise lower grade ores to above 35 per cent, which gave them free licence of disposal of the dressed ores, along with the large tonnages above that level that were naturally found in the mine.

The first agreement stipulated that 10,000 tons of ore were to be delivered (at 21 cwt to the ton) between April 1849 and April 1850, and 30,000 tons over each of the remaining six years of the contract should the mine produce so much. Ore delivered during one-month was to be paid for in copper in the course of the third month

following.⁵¹ As it turned out, SAMA was unable to produce 30,000 tons per annum but even on reduced tonnages difficulties were experienced by the smelters in supplying the appropriate copper returns within the stipulated period. That was resolved in 1851 when the agreement was amended to allow arrears of copper to be settled in cash.⁵² While occasional difficulties such as inclement weather that disrupted fuel supplies might have been responsible for problems, there were other occasions when the PCC appeared to openly abuse its contract. Thus, for example, when behind in its obligations to SAMA in 1851, the PCC was blatantly exporting large tonnages of copper to Calcutta, Bombay and Singapore,⁵³ or sending high grade ores to the parent Spitty Works in Wales. In 1856, however, the smelters sold the Spitty concern and thereafter concentrated all their activities within Australia and also drew up a new five-year contract whereby they obtained the whole of SAMAs production of ore.

Transport and Fuel

The question that arises is whether the PCC and E&ACC made a sensible decision in locating at Kooringa? The decision was made on the assumption that the Napier process would allow them to overcome the problems of distance and that the area of location was favourable in terms of access to vital raw materials. The reduction of processes involved in the production of copper from six or eight to two has already been mentioned. This would have led to a saving of fuel, fluxes and labour.⁵⁴ Of the former, adequate supplies of wood and charcoal had been proved locally and while in the initial stages the PCC relied on the importation of salt and pig iron that were used as fluxes, the latter material was soon discovered locally, especially at SAMAs Karkulto Mine,⁵⁵ as was silica. By January 1850, the need for salt had been eliminated, either because imported anthracite made its use redundant or because through experimentation the smelters discovered that using higher percentage ore eliminated the need.⁵⁶ While building and firebricks were also initially imported from Britain in their thousands,⁵⁷ this was probably because they made suitable ballast and were therefore cheap and convenient to import, but even before the arrival of Walters, deposits of clay had been discovered in the locality of the mine that made fire-bricks of high quality that more than met the needs of the PCC.⁵⁸

Various estimates have been made of the amount of coal required to smelt the ores. The British, *Mining Journal* reported that the Burra ores were smelted at a ratio of one ton of ore to two tons of coal.⁵⁹ Cumming estimated from aggregate figures that in 1852 the PCCs ratio was one to one to produce a quarter of a ton of copper.⁶⁰ James Hamilton, who became manager of the E&ACC reported in 1857 that it took 15,000 tons of coal to smelt 12,000 tons of ore⁶¹ – thus a ratio of 5:4 or 1.25:1, while Henry Ayers gave a 1:1 relationship, though stating some ‘intractable ores require two tons of coal, and one ton of another metal for each ton of ore’.⁶² Overtime, there were also improvements in efficiency, as suggested by E&ACCs manager, James Hamilton’s statement in 1859, that he was making 25 per cent more copper with the same amount of fuel that had been used previously.⁶³

Such figures help explain why the smelters believed that locating near the Burra mine would not represent a burden. It was explained that as long as ‘up’ traffic balanced the ‘down’ traffic then there was no great benefit in locating near Port Adelaide, for whether utilising their own transport from their depot at Port Wakefield, as was the case with the smelters, or in hiring private transport, as was the case with SAMA, the cost for a one way journey was roughly the same as for a return journey.⁶⁴ This was also the argument used by the South Australian Railway officials whose main concern was to cover the cost of a return journey – the reason they gave for extending preferential

treatment to the smelters when the latter began to utilise the railway from the time it was extended from Gawler to Kapunda in 1857.⁶⁵ Coal and miscellaneous materials were taken from Port Adelaide to Kooringa and this was balanced by the back loading of copper and copper ore. When asked in 1857 whether he would benefit by relocating the works to Port Adelaide, E&ACC manager, James Hamilton stated 'it would be absurd, I think, to do so', for not only would they have to bring down the ore from the mine to the new smelter but would also be required to cart 3,000 tons of iron ore for fluxes from the locality. In addition, he pointed to the fire-clay, available only on their own property, that would have to be conveyed, plus the large quantity of wood for charcoal used in the smelting, which would be unavailable at the Port. Of the latter, they had 6,000 tons in stock at that time.⁶⁶ However, Hamilton did admit that while on occasion they relied on wood entirely, there was a preference for coal in the smelting process,⁶⁷ though uncertainty of supply made that preference merely wishful.

One advantage in locating at Kooringa was the fact that while coal supplies from New South Wales or Swansea were often disrupted because of communication problems, or shortage of supply,⁶⁸ they could always be certain of large wood fuel supplies locally. Substitution could also prove attractive when coal prices soared in relation to the cost of wood fuel, the latter tending to be much more stable (See Appendix 1). Henry Ayers noted that 'wood is used in considerable quantities for smelting, and the consumption of coal is reduced in proportion',⁶⁹ thus qualifying that the smelters switched fuel sources either to balance the up and down traffic or to substitute when coal was in short supply. To give some idea of the proportions used, between October 1848 and July 1852, the smelters expended £15,826 on coal and £26,467 on wood fuel specifically for smelting purposes.⁷⁰ When estimating relative costs, it was generally agreed that three tons of wood fuel did the work of one ton of coal.⁷¹ Calculating in 1873, at a time when transport costs had declined substantially (see Appendix 1), Henry Ayers concluded that at the ratio of 1:3, purchasing coal at 31 shillings per ton at the Port, plus 25 shillings land transport was virtually the same as purchasing wood at Kooringa at 18 shillings per ton (56 shillings for coal as against 54 shillings for wood) – and this at a time when the price of wood had risen because of shortage of drays.⁷² In the earlier years of smelting, that advantage would have been even greater not only on a cost basis but also on availability, for the smelters up until the end of 1854 relied on imports of coal from Britain – a supply that was irregular and uncertain. Only from that year did the smelters regularly seek coal from New South Wales. At first there was reluctance by the PCC and E&ACC to use this source, as they believed that Newcastle and Bulli coals were inferior to the Welsh anthracite that they had used. They had in fact stockpiled NSW coal at their Port Wakefield depot for three years before being forced to use it because of delays in British coal shipments. They were surprised to find that it served their purpose. As the E&ACC manager, James Hamilton reported:

I have been gratified to find that NSW coal is proving better quality than expected. Mr Williams thinks that long exposure to the atmosphere may have improved it ... the furnaces have been melting 34 tons per week; they have rarely done so well, and the coal has been almost wholly Sydney Coal. It is true that the quantity consumed is somewhat greater, but it is not really so, because the Sydney coal is not so clean as it should or might be.⁷³

Thereafter, but especially after 1856 when they reduced copper ore shipments they turned more and more to NSW and especially Newcastle. This followed sale of the E&ACCs Spitty smelter in South Wales, which meant they no longer received special

shipments of coal as return cargo or ballast from Swansea. However, it didn't fully satisfy their coal supply problems because of lags in delivery from Newcastle to South Australia and they continued to substitute wood. Even during the 1870s, SAMA was complaining as to the expense and uncertainty of coal deliveries to the Port.⁷⁴

Wood was not only plentiful, as witnessed by the vast consumption of that product by both the smelter and SAMA but with a surfeit of carters in the vicinity there were relatively few periods when stockpiles dwindled to dangerous levels. Timber licences were available for cutting on Crown lands for a fee of £5 per annum and there were plenty of workers prepared to pay this sum while demand for the product remained high. There was also a large supply of carters, so much so that on occasions, would-be suppliers were turned away. Strategies were also used to keep down prices, one being cooperation between the smelters and miners who had a shared interest in keeping down costs.⁷⁵ Stockpiling was one method adopted and this was done in the less active periods of the agrarian year when farmers were anxious to provide their services. There were also many individual carters but also large contractors – and all of these could be played off against each other to ensure lower cartage costs.⁷⁶ In addition, the smelters would use their own extensive transport supply to satisfy their needs.⁷⁷ To illustrate just one of the strategies adopted: with the partial shutdown of the Burra Mine in 1867, the directors ordered that contracts should be set at monthly periods to ensure that tenders would be competitive. In that period they additionally ruled that limits be set on the number of 'casual' suppliers, thus forcing such suppliers to bid keenly against other casual suppliers, and at a price equal to or below that of the contractors. Under this system prices as low as 10 shillings per ton for dry wood were obtained.⁷⁸ In 1872, a bid to supply 3,600 tons of firewood at 70 tons per week was answered by William Woollacott. The tender was accepted but only on condition that he would accept the same price as the Totshill farmers who had promised to deliver firewood rather than to arrive at Koorunga with empty drays while on their way to pick up stores at Koorunga. Woollacott accepted and was paid 12 shillings for dry and 10 shillings for green wood.⁷⁹ The keen competition is also illustrated by E&ACCs, James Hamilton's statement in 1857, that he paid for cartage of wood, only eight shillings, or little over 2 1/2 pence per mile on a round trip of 30 miles, at which price 'they were doing nothing at it'.⁸⁰

But not all was well for the E&ACC, a situation realized by Henry Ayers who remarked in 1854 that 'The fact is Copper Smelting in South Australia never has paid and the prospects of its succeeding now are less than ever'.⁸¹ He was correct for the smelters did not pay their first dividend on their South Australian venture until 1857.⁸² Ayers was in fact convinced of their dependence on SAMA and in 1856 when the 1851 contract was coming to an end he confided that:

They [EACC] must make another contract with us, or otherwise their loss will be very great the bulk of their colonial property would be almost valueless in the absence of an agreement with us.⁸³

A new contract was signed in 1856 that saw some improvement in the returns of copper from low-grade ores to the E&ACC and also gave them or SAMA the option of pulling out of the contract should either be dissatisfied.⁸⁴ But the smelters were mollified by the higher returns they had been granted and also by the realization that problems experienced during the goldrush were now behind, and for a few years their fortunes improved.

Part of that improvement was associated with a change in the transport situation, for the arrival of the railway at Gawler saw them abandon their Port Wakefield route for the more direct route to Port Adelaide. Transporting via Port Wakefield had in fact been a burden to them from the time they adopted the route in 1849, though poor accounting procedure was probably the reason that they failed to realize this sooner than 1857.⁸⁵ As James Hamilton put it, ‘even in the best of seasons, the smelting works’ transport bills continued to eat up our profits’.⁸⁶ But even though the railway crept ever closer to Burra, reaching Kapunda some 80km away by 1860, the E&ACC decided at that time to set up plant at their wharf in Port Adelaide, despite the improved transportation.

A shift in location

Henry Brown put the decision to locate at the Port to declining production at the Burra mines and the desire to capture production of the Moonta and Wallaroo Mines.⁸⁷ However, as production in 1860 was the third highest recorded at the mine this was an unlikely reason. As the Moonta Mine was discovered a month after work on the new smelter had begun on 18 May 1861 neither was this a possible reason. While the Wallaroo Mine was discovered in 1859, it was slow to develop and by September 1860 only 500 tons had been raised and barely 200 men employed⁸⁸ In addition, such a decision would have been determined by the Company’s London directors and with the communication at the time - in 1855 mail taking at least 89 days to reach London - this makes it even more unlikely that Wallaroo production would have swayed the decision makers.

Bannear and Annear suggest that declining copper in the ores was probably the reason⁸⁹ but again there is little evidence of this at the time especially as ores could be, and were, dressed up by the miners to acceptable percentages. But there was another reason earlier raised by E&ACCs James Hamilton as to why other mines would not be a leading reason for a move:

We would not smelt sulphur there, it would destroy the crops for miles around, and it would be absurd to put up works if we could not smelt all kinds of ore. We should be indicted as a nuisance at the Port.⁹⁰

Hamilton reiterated this point after commencement of building the smelter, pointing out that ‘only low class ores from the Burra which do not contain the noxious quality’ would be used.⁹¹ Perhaps the *Mining Journal* had the right answer when it reported that the Port Adelaide Works had been established to save carriage from Koorunga but that it had since been extended to allow for ores from Wallaroo and other mines.⁹² The development of a new smelter possibly allowed them to adopt improved cost cutting techniques, which might have been another reason for the move. Production figures for the six months ending December 1863 record production at Koorunga as £25 7s per ton to produce refined copper, as against \$17 17s at the Port, a very substantial saving.⁹³ Possibly the smelters in the hope of maintaining their monopoly realised that to maintain their hold over SAMA ores they had to reduce costs in order to offer more attractive terms.⁹⁴ There is little doubt that the E&ACC were concerned, for not only had SAMA threatened to ship its ores directly to Swansea⁹⁵ but had also been in negotiation for some time with William Henderson with respect to adopting his process of reducing ores with sulphuric acid. By continuing at Koorunga, the smelters had nothing to gain and everything to lose. By moving to Adelaide they could offer more generous terms so as to monopolise SAMAs ores and could also possibly attract production from other mines and also regulus for refining from other smelters.

For a number of years the E&ACC continued to smelt at Kooringa while also smelting at Port Adelaide but the decision from 1864 to utilise Kooringa for producing regulus and to concentrate most of the refining at Port Adelaide turned out to be fortuitous. In the first place production at the Burra Mine declined substantially from 1860/1861 when it produced 13,346 tons, to 2,002 tons of poor ores in 1868. The smelters still continued to send Newcastle coal to Kooringa with most of the activity being now directed at reducing the ore to regulus. The conveyance of regulus and low-grade ores from the Mine but in addition fire clay, iron ore and silica, again saw balanced transportation to and from Kooringa. That balance was also maintained by continuing to augment coal through the use of local wood fuel from the Mallee Scrub. From 1869 to 1871, activity virtually came to a halt as the miners attempted to reconstruct by shifting to open cast mining. The last smelting took place at Kooringa in 1869 when a total of 500 tons of ore was reduced to regulus.⁹⁶ From 1871 to 1877 when the Mine finally closed, it was agreed that all ores from Burra would be sold to the E&ACC at Port Adelaide for cash and not exchanged for copper as previously practiced.

In the meanwhile, the E&ACC had reduced its costs through use of the railway to Kapunda by managing to negotiate preferential carriage rates because of its large and year-round custom. In 1861, the firm received special mention by the Railway manager as being the most important customer on the Northern Line, providing in a period of four-and-a-half months 'the noble quantity of 10,100 tons of coals, etc.'⁹⁷ Knowing their strength, during that year the E&ACC threatened to carry all its produce by dray unless coal freight charges were reduced by 2 shillings per ton (1/2 penny per ton mile). The Railway Commissioners not only conceded to this threat but extended the benefit to goods carried between October 1860 and June 1861.⁹⁸ SAMA did not enjoy this advantage but from 1870 when the railway at last reached Burra, rates were charged at 3.0 pence per ton-mile, a halving of previous carriage costs – though perhaps because of their limited production, a little late for the miners to reap any great benefits.

In 1869 the E&ACC began erection of a new smelter at New Lambton, Newcastle, NSW. This opened for business in 1871 and SAMA ended their activities by agreeing to do what they had determined not to do in 1845/46 – to take their ores to the fuel when selling to the E&ACC at Port Adelaide and to the New Lambton Smelting Works in Newcastle.⁹⁹

Examining the figures in column 3, Appendix 2, it will be seen that taking the extremes of recorded high and of low combinations of coal and transport costs, there was an overwhelming advantage in terms of smelting costs throughout the period when using wood rather than coal as a fuel. Also taking into consideration the uncertainty of obtaining supplies of coal for much of the period, including the latter years of activity at the mine; the ready availability of fire-clay, fluxes and other necessary raw materials at Kooringa; and the fact that there was a calculated balance between materials moving to and moving from the coast and the mine; the decision to smelt at Kooringa appears to have been rational. The problems faced by the smelters had more to do with the haste with which they signed their first contract than with fuel supplies, and when it came to renewing the contract they were placed in a poor bargaining position because of the capital they had tied up at the location and their need to ascertain supplies of Burra ores, to be able to function profitably. By the time the Newcastle smelter opened in 1871, SAMAs position had greatly weakened and it had little choice but to take its ores to the fuel.

APPENDIX 1

Coal and wood fuel prices per ton at Kooringa 1849 – 1876 (Shillings/pence)

	1		2			3		4			5		6		7	
Year	Coal price at <u>Pt. Adelaide</u>		Coal price at <u>New South Wales</u>			Coal freight NSW <u>to Pt Adelaide</u>		Quoted Land carriage Pt <u>Adelaide to Kooringa</u>			Estimated Coal <u>price Kooringa</u>		Quoted firewood <u>price Kooringa</u>		Specific coal prices <u>quoted at Kooringa</u>	
	High	Low	High	Coghlan	Low	High	Low	High	Approx.	Low	High	Low	High	Low	E&ACC	
1849	30s 0d	7s 2d *	6s 0d					55s 0d		25s 0d	85s 0d	32s 2d	12s 0d	7s 0d		
1850	20s 0d	12s 0d *	6s 7d					50s 0d		35s 0d	70s 0d	47s 0d	22s 0d	15s 0d		
1851	36s 0d	14s 0d *	9s 0d	7s 7d	6s 6d			50s 0d		35s 0d	86s 0d	49s 0d	20s 0d	10s 0d		
1852	120s 0d	10s 0d *	10s 11d 7s 6d					60s 0d		40s 0d	180s 0d	50s 0d	40s 0d			
1853	151s 7d	52s 6d *	21s 0d	16s 2d				70s 0d		50 s 0d	221s 7d	102s 6d	20s 0d	12s 6d		
1854	140s 0d	18s 0d *	20s 6d					80s 0d		60 s 0d	220s 0d	78s 0d	22s 6d			
1855	70s 0d	16s 7d *	13s.0d					80s 0d		60 s 0d	150s 0d	76s 7d	25s 0d	20s 0d		
1856	50s 0d	12s 9d *	12s 4d					100s 0d		50 s 0d	150s 0d	62s 9d	17s 0d			
1857	46s 0d	45s 0d	15s 7d	14s 1d	13s 0d	30s 0d	29s 0d	60s 0d		50s 0d	106s 0d	92s 0d	17s 6d	12s 0d		
1858	45s 0d	36s 0d	21s 0d	15s 0d	15s 0d	30s 0d	27s 6d	50s 0d		35s 0d	101s 0d	71s 0d	16s 9d	15s 0d		
1859	40s 0d	38s 0d	15s 0d	13s 3d	13s 1d	27s 6d	23s 0d	70s 0d		47s 0d	112s 6d	83s 1d	20s 0d	15s 0d	140s 0d	85s 0d
1860	-	-	14s 3d	12s 3d	12s 3d	26s 0d	21s 0d	60s 0d		40s 0d	100s 3d	73s 3d	20s 0d	16s 9d	85s 0d	
1861	32s 0d	32s 0d	14s 3d	12s 9d	12s 9d	26s 0d	20s 9d	60s 0d		40s 0d	100s 3d	73s 6d	14s 6d	13s 3d	87s 4d	
1862	40s 0d	34s 9d	19s 0d	12s 9d	13s 0d	22s 0d	21s 0d		50s 0d		91s 0d	84s 0d	19s 0d	11s 3d	85s 0d	
1863	36s 6d	23s 0d	14s 6d	10s 10d	5s 0d	24s 9d	10s 0d		50s 0d		89s 3d	65s 0d	20s 0d	10s 6d	78s 0d	
1864	27s 6d	18s 6d	9s 10d	9s 10d	2s 0d	24s 0d	10s 0d	50s 0d		48s 0d	83s 10d	60s 0d	16s 6d	13s 0d	65s 0d	
1865	26s 0d	18s 6d	9s 4d			21s 0d	18s 9d		50s 0d		80s 4d	68s 6d			75s 0d	
1866	26s 0d	18s 9d	8s 4d			18s 9d			50s 0d		76s 0d	68s 9d	17s 6d	15s 0d	80s 0d	
1867	26s 0d	19s 0d	8s 10d			20s 3d	19s 9d		50s 0d		76s 0d	69s 0d	12s 6d	10s 0d	80s 0d	
1868	29s 0d	21s 0d	20s 9d	8s 9d	20s 9d	27s 6d	20 s 9d		50s 0d		97s 6d	71s 0d	13s 0d	12s 6d	70s 0d	
1869	23s 6d	16s 0d	7s 6d			21s 0d			50s 0d		78s 6d	66s 0d			75s 0d	
1870	17s 9d	17s 9d	7s 4d	7s 3d		22s 0d	17s 9d		50s 0d		79s 4d	67s 9d				
1871	24s 0d	15s 0d	7s 0d	7s 0d	3s 0d	17s 9d	12s 0d		25s 0d		49s 9d	40s 0d	12s 0d	10s 0d		
1872	27s 6d	16s 9d	4s 0d	7s 9d	3s 0d	25s 0d	12s 0d		25s 0d		54s 0d	40s 0d	14s 0d	10s 0d		
1873	31s 0d	24s 0d	6s 0d	11s 2d	5s 0d	24s 0d	18s 0d		25s 0d		56s 0d	48s 0d	18s 0d	7s 0d	56s 0d	
1874	32s 6d	23s 0d	14s 0d	12s 1d	4s 0d	24s 0d	23s 0d		25s 0d		63s 0d	48s 0d	14s 0d	7s 0d	57s 6d	52s 0d
1875	35s 0d	25s 0d	12s 4d			24s 0d	23s 0d		25s 0d		61s 4d	50s 0d				
1876	24s 0d	14s 0d	12s 2d			10s 0d			25s 0d		49s 0d	39s 0d				

APPENDIX 1

Coal and wood fuel prices per ton at Kooringa 1849-1876 (shillings/pence)

Sources and Notes

Column 1:

All figures from ledgers, journals and cash books of the Patent Copper Company, and the English and Australian Copper Company, Business Record Group 30 [hereafter BRG 30], State Library of South Australia [hereafter SLSA]. Figures marked * refer to British coal imports. There were only a few instances of coal from New South Wales being imported by the smelters before 1857. The reason probably relates to the sale of E&ACC's Spitty Works in Swansea in 1856, which saw regular shipments of copper ore to that port and the return of coal cargo and coal ballast to Port Adelaide cease. NSW thereafter supplied most of the coal. During the goldrush years 1852-56, very few shipments were received. From 1856, most coal received was supplied by a contractor, Henry Simpson & Sons. It is not known whether the various prices are for screened or unscreened coal. Coal prices are generally understated at Pt. Adelaide because wharfage and other charges have not been included.

Column 2:

High and low rates recorded from journals and cash books, BRG 30, SLSA. Coghlan figures from T.A. Coghlan, *The Wealth and Progress of N.S.W. 1886-87*, George Robertson, Sydney, 1887, p.91. Coghlan gave 'average' figures and these have been taken to the nearest penny. In T.A. Coghlan, *Labour and Industry in Australia from the First Settlement in 1788 to the Establishment of the Commonwealth in 1901*, MacMillan of Australia, 1969, 4 vols, vol. II, p. 686, it states that at the height of the goldrush, the price of coal at the pit's mouth rose to 32s 6d per ton. It is not known whether the various prices are for screened or unscreened coal.

Column 3:

Figures from journals and cash books, BRG 30, SLSA.

Column 4:

Figures from journals and cash books, BRG 30, SLSA; SAMA Directors Out-letter books, BRG 22/960, SLSA; Letters to SAMA Mine Officials, BRG 22/961, SLSA; Also see Mel Davies, 'Bullocks and Rail - The South Australian Mining Association 1845-70', *Australian Economic History Review*, Vol. XVII, no. 2, September 1977, pp. 150-165, and Mel Davies, 'Copper Connections – Burra routes and transport: a matter of economics?', *Journal of the Historical Society of South Australia*, no. 30, 2002, pp. 52-66, for figures and various references including reports in the *South Australian Parliamentary Papers* where transport prices are given. See also, Frank Treloar, *The Burra Mine. Reminiscences of its Rise and Fall, 1845-1877*, Burra Record, 1929, pp. 14, 32-33, 37, 41.

Column 5:

'High' derived from the highest possible combination of prices cited in previous columns, and 'Low' from the lowest possible combination.

Column 6:

Sources as per column 4.

Column 7:

See journals, BRG 30, SLSA.; Letters to SAMA Mine Officials, BRG 22/961, SLSA. The E&ACC price was referred to by the smelters as being the 'consumption price'.

APPENDIX 2

Comparative advantage/disadvantage of using wood fuel at Kooringa, taking the smelting ratio as 3 tons wood to 1 ton of coal and calculating on the basis of the highest and lowest costs recorded.

Year	1		2		3	
	Estimated cost of coal per ton at Kooringa *		Cost of using wood fuel at Kooringa at smelting ratio of 3:1		Cost advantage over coal in smelting copper ore with wood fuel at Kooringa	
	High	Low	High	Low	High	Low
1849	85s 0d	32s 2d	36s 0d	21s 0d	49s 0d	11s 2d
1850	70s 0d	47s 0d	66s 0d	45s 0d	4s 0d	2s 0d
1851	86s 0d	49s 0d	60s 0d	30s 0d	26s 0d	19s 0d
1852	180s 0d	50s 0d	120s 0d	120s 0d	60s 0d	(-)70s 0d
1853	221s 7d	102s 6d	60s 0d	37s 6d	161s 7d	65s 0d
1854	220s 0d	78s 0d	67s 6d	67s 6d	163s 6d	11s 6d
1855	150s 0d	76s 7d	75s 0d	60s 0d	75s 0d	16s 7d
1856	150s 0d	62s 9d	51s 0d	51s 0d	99s 0d	11s 9d
1857	106s 0d	92s 0d	52s 6d	36s 0d	53s 6d	36s 7d
1858	101s 0d	71s 0d	50s 3d	45s 0d	50s 9d	26s 0d
1859	112s 6d	83s 1d	60s 0d	45s 0d	52s 6d	38s 1d
1860	100s 3d	73s 3d	60s 0d	50s 3d	40s 3d	23s 0d
1861	100s 3d	73s 6d	43s 6d	39s 9d	56s 9d	33s 9d
1862	91s 3d	84s 0d	57s 0d	33s 9d	34s 3d	50s 3d
1863	89s 3d	65 0d	60s 0d	31s 6d	39s 3d	23s 6d
1864	83s 10d	60s 0d	49s 6d	39s 0d	34s 4d	21s 0d
1865	80s 4d	68s 6d				
1866	76s 0d	68s 9d	52s 6d	45s 0d	33s 6d	23s 9d
1867	76s 0d	69s 0d	37s 6d	30s 0d	38s 6d	39s 0d
1868	97s 6d	71s 0d	39s 0d	36s 6d	58s 6d	34s 6d
1869	78s 6d	66s 0d				
1870	79s 4d	67s 9d				
1871	49s 9d	40s 0d	36s 0d	30s 0d	13s 9d	10s 0d
1872	54s 0d	40s 0d	42s 0d	30s 6d	12s 0d	9s 6d
1873	56s 0d	48s 0d	54s 0d	21s 0d	2s 0d	23s 0d
1874	63s 0d	48s 0d	52s 0d	21s 0d	11s 0d	27s 0d
1875	61s 4d	50s 0d				
1876	49s 0d	39s 0d				
	* From column 5 Appendix 1		Figures calculated from column 6, Appendix 1, by multiplying high and low prices by three.			

Sources: As per Appendix 1.

Notes: Had the ore been taken to Port Adelaide without being smelted, then land carriage costs would have been multiplied by at least three per ton because of the large amount of waste in the ore, even after it had been dressed.

In 1869 the mine ceased production for two years, though 500 tons of ore was smelted that year. From 1871, ore was transported by SAMA directly to Port Adelaide. However, wood fuel continued to be used by SAMA to drive machinery they had installed.

Endnotes

¹ The following conversions can be used for the many measurements in this article: one ton = 0.9072 tonne; 1 hundredweight (cwt) = 0.0454 tonne; 1 pound (lb) = 0.4536 kilogram; 1 acre = 0.4047 hectare; 1 bushel = 0.03524 meter³.

² Quoted in the *Register* (South Australia), 24 September 1845, p.3, column b. For later comment from the *Maitland Mercury*, 14 November 1846, p. 486, see David Bannear and Robyn Annear, *The Burra Smelting Works. A survey of its history and archaeology*, District Council of Burra Burra, 1990, p. 19.

³ Donald Chaput, 'The Burra Burra Question: To Ship or to Smelt?', *Journal of the Historical Society of South Australia*, no. 12, 1984, p. 62; Bannear & Annear, *Burra Smelting Works*, p. 19. Some of SAMAs directors supported this move but were outvoted. See *The South Australian Register*, 27 September 1848.

⁴ *Ibid.*, 16 January 1847, p.29. Freight to Swansea or Newcastle was calculated at 20 shillings per ton, coal at 7s a ton and charcoal at 13s 7pence per ton. On 5 tons of 20 per cent ore this showed a cost of £3 7s for smelting at Koorunga as compared with £6 15s at the other two locations.

⁵ This is based on the fact that when the Association employed a smelter, the smelting company retained part of the proceeds. The writer when making a counterfactual analysis of mine production from 1845-77 has calculated that the Association would have provided its shareholders with greater returns had they sent all their ores to Swansea for sale. See, Mel Davies, 'The South Australian Mining Association and the marketing of copper and copper ores 1845-1877', MA thesis, Economics, University of Adelaide, 1977, ch. 7.

⁶ *The Mining Journal Railway and Commercial Gazette*, 13 June 1846 [hereafter *Mining Journal*], 'The Mineral Wealth of South Australia'.

⁷ 10 October 1845, Business Records Group [BRG] 22, 957, *Directors Minutes*, State Library of South Australia [SLSA], p. 51. See also *The South Australian Register*, 24 September 1845, where the editor stated there was enough wood to 'meet a vast consumption for generations to come, even if we discover no coal of our own'. However, *The Illustrated London News*, 2 December 1848, 'The Burra Burra Copper Mine in South Australia', stated there was a scarcity of timber in the Burra area and thus smelting would not succeed there. A similar comment was made in *The South Australian Register*, 29 August 1849 when reported that in a 10-mile radius around Burra the hills were denuded of trees. However, SAMA and the smelters were never to find obtaining supplies a problem and even in the late 1860s were turning down offers to supply wood from cutters and carters. In 1857, the Koorunga smelters reported that a plentiful supply was available at a distance of 15 miles and the quoted cartage at 2 1/2pence per mile for the 30mile round trip suggests that there were lots of carters and cutters keen to supply. See, *South Australian Parliamentary Papers* [hereafter *SAPP*], no. 97, 1857, 'Report of the Select Committee of the House of Assembly ... Gawler Railway Extension Bill; Minutes of Evidence', evidence Mr. James Hamilton, Manager of the English & Australian Copper Co., minutes 846-850.

⁸ The most common trees in the area were: Peppermint Gum, (*Eucalyptus Odorata*), Red Gum (*Eucalyptus Camelduleusis*), Long leaf Box (*Eucalyptus Goneocalyx*), She Oak (*Casuarina Stricta*), Blue Gum (*Eucalyptus Leucocton*), Marble Gum (*Eucalyptus Goniocalyx*), plus various acacias and mallee. Before clearing, the general description of the area would have been 'Open Savannah Woodland'. See D.N. Kraehenbuehl, 'The Distribution and Relationship of Flora and Fauna, in the Tothill Range South Australia', Unpublished report, South Australian Museum. R.L. Specht, *The Vegetation of South Australia*, Government Printer, 2nd ed., 1972, p. 201, fig. 126, described the current vegetation in the Burra area as 'tussock grassland', which indicates the extent of clearing since the 1840s. Michael Williams, *The Making of the South Australian Landscape: A study in the historical geography of Australia*, Academic Press, London/New York, 1974, p. 134, states that Burra was 'on the edge of naturally treeless, grassy plains ... a considerable distance from the stringybark forests ... [but] within ten miles of the mallee scrub land, a future source of fuel'. Frank Treloar, *The Burra Mine: reminiscences of Its rise and Fall 1845-1877*, Burra Record Office, p.14, recalled that in 1849, 'Wood was then plentiful near at hand'. This observation is supported by the German smelters, who stated that there were 500 trees in the Burra Creek alone and that each tree would supply two furnaces for two days, enough to smelt eight tons of ore. See, 10 October 1845, p. 51, BRG 22, 957, SLSA.

⁹ 22 September 1845, BRG 957, SLSA.

¹⁰ *The Mining Journal*, 22 April 1848, 'Mining in South Australia', reported that Dreyer had 22 years experience of smelting copper with charcoal in the Hartz Mountains.

¹¹ 30 September 1845, BRG 22, 957, pp. 47-48, SLSA; *Ibid.*, 10 October 1845, p.51; *Ibid.*, - November 1845.

¹² *Ibid.*, 3 December 1845, p.66.

- ¹³ *Ibid.*, 10 October 1845, p.51; 12 January 1846, Henry Ayers to F.V. Sommers BRG 22, 80/38, *Miscellaneous Papers*, SLISA; 15 April 1846, BRG 22, 959, *Minutes of Meetings of Shareholders*, SLISA.
- ¹⁴ Superintendent to H. Ayers, 29 September 1847, BRG 22, 967, *Superintendent's Letter Book, 18 September 1847 to 19 December 1849*; no. 31, H. Ayers to Thomas Roberts, BRG 22, 960, SLISA.
- ¹⁵ *Ibid.*; *Ibid.*, Superintendent to H. Ayers, 5 October 1847, no. 4. Problems were described as being associated with the horse and bullock whim that drove the bellows; with the vibration that threatened to shake to pieces the wooden parts linked to the bellows; and the effort to drive the whim, which stated the Superintendent, 'knocks up the horses'.
- ¹⁶ Superintendent to H. Ayers, 29 September 1847, BRG 22, 967, SLISA.
- ¹⁷ *Ibid.*, 29 September 1847, no. 4.
- ¹⁸ Geoffrey Blainey, *The Rush that Never Ended, A History of Australian Mining*, Melbourne UP, 2nd edn, 1969, p. 110, states that Davy was a physician, chemist and journalist who a decade earlier than 1846 had invented the method of relaying the telegraphic message. He was also a close relation of Sir Humphrey Davy who invented the Safety Lamp.
- ¹⁹ 31 December 1845, p. 68, BRG 22, 957, SLISA.
- ²⁰ *The South Australian Register*, 13 December 1845.
- ²¹ 6 January 1846, BRG 22 957, SLISA, p.69; *Ibid.*, 14 July 1847, p.107; 18 July 1846; H. Ayers to Dr E. Davy, 18 July 1846, no. 204, *Directors Out-Letter Books*, BRG 960, SLISA.
- ²² 4 August 1846, p. 109, BRG 22, 957, SLISA; *Ibid.*, 18 August 1846, p. 112.
- ²³ Bannear & Annear, *Burra Smelting Works*, p. 21.
- ²⁴ For this information and for some details on the patent for Davy's process, see D.A. Cumming, 'Processing of Copper Ores in South Australia', *Report no. G10*, Department of Civil Engineering, The University of Adelaide, May 1982, p 4, copy of paper presented to the Conference on the Protection of the Engineering Heritage, Brisbane, 1982.
- ²⁵ 14 September 1849, p. 265, BRG 22, 957, SLISA; *Ibid.* 16 October 1849, p.273; *Ibid.*, 4 August 1853, p.71; H. Ayers to E.C. Gwynne, Esq., 29 December 1849, no. 993, BRG 22, 960, SLISA.
- ²⁶ Bannear and Annear, *Burra Smelting Works*, p. 22, states that 'Penny had spent years in Mexico, mining, while Owen had trained as a chemist in England'. It appears that Owen gave up his interest in the Apoina smelter between 1849-50. In addition to C.M. Penny, there were two other 'Penny's' in the colony: C.S. Penny was manager at the Glen Osmond Lead Smelter, and probably the person with the same name who was one of SAMAs directors, while H.F. Penny acted as that company's agent in Adelaide. For further details see, James Allen, *The South Australian Almanack and General Colonial Directory*, Adelaide, 1849, p.129; *The South Australian Almanack and General Colonial Directory*, Adelaide, 1850, p. 73; Andrew Murray, *The South Australian Almanack and General Colonial Directory for 1851*, Andrew Murray, Adelaide, 1851, p. 65.
- ²⁷ For details of C.M. Penny's patent, see *The Mining Journal*, 10 March 1849, 'Improvements in the Smelting of Ores'. A brief description of the smelter can be found in E.M. Yelland (ed.), *Colonists, Copper, Corn in the Colony of South Australia 1850-51, by Old Colonist*, Hawthorn Press, Melbourne, 1970, p. 147. See also, R.J. Noye, *The Midlands Chronicle History*, Saddleworth District Historical Society, 1967, vol. 1, pp. 13-15; Cumming, 'Processing of Copper Ores', pp. 4-5.
- ²⁸ H. Ayers to Messrs. Penny & Owen, 2 October 1847, BRG 960, SLISA.
- ²⁹ Bannear & Annear, *Burra Smelting Works*, p. 22.
- ³⁰ H. Ayers to Messrs. Penny & Owen, 2 October 1847, BRG 960, SLISA.
- ³¹ See for example, *Ibid.*, H. Ayers to C.M. Penny, Apoina, 2 November 1850, no. 1197, where stated that only 260 tons of ore had been removed by Penny in four months, and that in the previous month only 50 tons of 250 tons set aside had been collected.
- ³² Bannear & Annear, *Burra Smelting Works*, p. 23.
- ³³ H. Ayers to Charles M. Penny, Apoina Smelting Works, 26 January 1850, BRG 22, 960, no. 1021, SLISA. Bannear & Annear, *Burra Smelting Works*, p.23, come to a different conclusion than the author when they claim that apart from inability to take up sufficient ore tonnages, the SAMA directors were satisfied with the results.
- ³⁴ Unit = each percentile of copper in the ore. Thus 30 per cent ore sold at 10s per unit would cost 30 x 10s = £15.
- ³⁵ Comment by H. Vivian Swansea smelting proprietor in the *The Mining Journal*, 17 August 1850, 'The Copper works at Swansea'. See also *The Cambrian*, 16 August 1850, p.3.
- ³⁶ Nicol Brown and Charles Corbett Turnbull, *A Century of Copper*, London, 1899, 1900, in 2 parts, part 1, pp. 36-43. See also, *The Mining Journal*, 17 August 1850, 'The Copper Works at Swansea'; *The Adelaide Observer*, 24 March 1853, 'The Burra Burra Mines and Smelting Works'; 'Report of the Select Committee of the House of Assembly on the Present Mineral Law', *SAPP*, no. 51, 1862, evidence H.

Ayers, minute 1035; and comments in J.B. Austin, *The Mines of South Australia, Including Also an Account of the Smelting Works in that Colony together with a Brief Description of the Country and Incidents of Travel in the Bush*, William Kyffin Thomas, Adelaide, 1863. Reprinted, Australian Facsimile Edition no. 48, Adelaide Libraries Board of South Australia, 1968.

³⁷ See comment in *Ibid.*, p. 99.

³⁸ Bannear & Annear, *Burra Smelting Works*, Appendix A, p. 109

³⁹ D.A. Cumming, *Notes on the Burra Mine and Smelter, for the Country Weekend of the South Australian Division*, The Institution of Engineers Australia, Department of Civil Engineering, The University of Adelaide, November 1982, pp. 54, 68. Bannear & Annear, *Burra Smelting Works*, p. 32. *Ibid.*, p. 25, provides some details of the processes involved when using a combination of sulphurets and the Burra ores, and the extended patent which removed the need for sulphurets.

⁴⁰ Walters died 29 October 1876 in England. Involved in mercantile trade at a young age, he became a junior partner in the firm of Messrs. Gower Nephews. His abilities being recognized, Messrs John Schneider & Co. engaged him in 1847 to organize the Patent Copper Company in South Australia, and he was responsible for drawing up the smelting contract with SAMA. He left Adelaide in 1856 and following the return of the Youngusband Ministry in 1858 was appointed as the first Agent-General for South Australia, a position that he held until 1865. See, 'South Australia and its First Two Agents-General', pamphlet printed by Spottiswoode & Co., London from *The Westminster Review*, no. 2634, vol. 13, 1883.

⁴¹ 24 October 1848, p. 220, BRG 22, 957, SLSA.

⁴² H. Ayers to G.S. Walters, esq., Manager Patent Copper Co., 8 September 1848, no. 616, BRG 22, 960, SLSA.

⁴³ *Ibid.*, 1 December 1848, pp. 226-7.

⁴⁴ *Ibid.*

⁴⁵ H. Ayers to J.B. Graham, 25 April 1849, no. 11, Private Record Group 100 [hereafter PRG 100], Papers relating to John Benjamin Graham, SLSA.

⁴⁶ *The South Australian Register*, 16 December 1848.

⁴⁷ Murray, *South Australian Almanack*, 1850, p. 103. For details on the equipment and manpower brought by the PCC to South Australia, see Bannear & Annear, *Burra Smelting Works*, p. 27. See BRG 30, *PCC/E&ACC Records*, Ledger 1, p. 183, SLSA, where noted that the fixed plant was valued at £65,349 on 30 June 1852 and £147,856 on 30 June 1856.

⁴⁸ While SAMA accepted the takeover of the new company in September 1853, evidence in the Smelter's Ledgers show that the Schneider Brothers sold out their interest to the English & Australian Copper Company on 8 January 1852. See Ledger 1, pp. 47-52, BRG 30, SLSA; 8 September 1853, p. 76, BRG 22, 957, SLSA. This is confirmed in *The Cambrian* [Swansea], 5 December 1851, p. 3, column a, where stated that arrangements had been made to hand over the company to the new proprietors. There was in fact little difference in the ownership, with Henry Schneider continuing to be at the helm. For some financial details of the takeover see, Cumming, *Notes on the Burra Mine and Smelter*, p. 36.

⁴⁹ H. Ayers to G.S. Walters Esq., Manager Patent Copper Co., 8 September 1848, no. 616, BRG 22, 960, SLSA. Outside of some minor adjustments in 1856 that relieved the smelters from taking 10 or 11 per cent ores and providing them with slightly lower returns in copper to SAMA, the scheme continued virtually unchanged. See *Ibid.*, H. Ayers to James Hamilton, Manager, English & Australian Copper Company, 5 September 1856, no. 63.

⁵⁰ H. Ayers to J.B. Graham, 14 February 1849, no. 7, PRG 100, SLSA.

⁵¹ H. Ayers to G.S. Walters Esq., Manager Patent Copper Co., 8 September 1848, no. 616, BRG 22, 960, SLSA.

⁵² *Ibid.*, H. Ayers to G.S. Walters, Manager, Patent Copper Co., 27 June 1851, no. 1347; *Ibid.*, H. Ayers to D.C. Mackey & Co., Calcutta, 9 September 1851, no. 1394; 5 June 1851, BRG 22, 957, p. 356, SLSA. Arrears cash payments were based on the copper price of the day. In August 1854, for example, the smelters were asked to pay £110 per ton, which, stated H. Ayers, allowed them £6 to £7 per ton over the market selling price. Interest was also charged by SAMA on arrears but until September 1856, SAMA was also obliged to pay interest to the smelter on early returns of copper. See H. Ayers to James Hamilton, Manager, English & Australian Copper Co., 5 October 1854, no. 1977, BRG 22, 960, SLSA; *Ibid.*, 5 September 1856, no. 63, SLSA.

⁵³ 13 November 1851, BRG 22, 957, p. 382, SLSA; Ledger 1, BRG 30, p. 134, SLSA.

⁵⁴ See observation on this point in the *Sydney Morning Herald*, 3, 10 and 17 May 1851, quoted in Bannear & Annear, *Burra Smelting Works*, p. 33.

⁵⁵ Cumming, *Notes on the Burra Mine*, p.44. Cumming notes that locally mined manganese was also used as a flux by the smelters. Bannear & Annear, *Burra Smelting Works*, pp. 54-55 mention iron ore as being

obtained from a number of properties in the vicinity of Burra, including mines the smelters opened near Black Springs and at Leighton.

⁵⁶ *Ibid.*; Cumming, 'Processing of Copper Ores', p. 3, quoting from the *South Australian Gazette and Mining Journal*, 6 February 1848, stated that when smelting sulphur free ores, 'Sand, lime and oxide or carbonate of iron could be added to satisfy the proportions of silica. To one ton of ore containing 12% copper (80lb) 36kg of common salt (50lb) 22kg of lime and (100lb) 45kg of anthracite should be added, and the mixture fused for six hours. If the ore was richer; less salt and more anthracite should be added'.

⁵⁷ From April to the end of December 1849 alone, some 238,000 bricks along with sand and fireclay were imported to Burra from Britain. See, Bannear & Annear, *Burra Smelting Works*, p. 87

⁵⁸ Ledgers and Journals, BRG 30, SLSA. Bannear & Annear, *Burra Smelting Works*, p. 51, quote that 'These bricks stand better than the best Dinas, Stourbridge, or other imported bricks'.

⁵⁹ *The Mining Journal*, 27 September 1862.

⁶⁰ Cumming, *Notes on the Burra Mine*, p. 37

⁶¹ *SAPP*, no. 97, 'Gawler Railway Extension Bill' 1857, 'evidence Mr. James Hamilton, Manager of the English & Australian Copper Co., minute 785.

⁶² *SAPP*. No. 108, 'Report of the Select Committee of the Legislative Council ... on Railways and Tramways', 1857, evidence the Hon. H. Ayers, Secretary of the South Australian Mining Association, minute 2018.

⁶³ Bannear & Annear, *Burra Smelting Works*, p. 56.

⁶⁴ See, Mel Davies, 'Bullocks and Rail – The South Australian Mining Association 1845-70', *Australian Economic History Review*, vol. XVII, no. 2, September 1977, pp. 150-65.

⁶⁵ See for example, *SAPP*, no. 108, 'Railways and Tramways', 1857, evidence Mr. William Hanson, Chairman of the South Australian Railway Commissioners and Engineer, minute 293, where he stated that 'It is nearly the same to me, whether I get threepence per mile both ways, or sixpence one way'. See, also Mel Davies, 'Copper connections – Burra routes and transport: a matter of economics?', *Journal of the Historical Society of South Australia*, no. 30, 2002, pp. 52-66.

⁶⁶ *SAPP*, no. 97, 'Gawler Railway Extension Bill' 1857, evidence Mr. James Hamilton, Manager of the English & Australian Copper Co., minutes 811, 818, 832, 833.

⁶⁷ *Ibid.*, minute 834.

⁶⁸ The Kooringa smelter was erected as competition began to emerge in the Newcastle coal trade, for the Australian Agricultural Company lost the monopoly that it had held from 1829-1847. Thereafter, according to Susan Marsden, *Coals to Newcastle: A history of coal loading at the Port of Newcastle, New South Wales 1797-1997*, Bobby Graham Publishers, Wagga Wagga, NSW, 2002, p.6, the number of coal producers and loading facilities multiplied. However, even in the 1860s coal supplies from Newcastle to Adelaide were often unobtainable when required. At the time of the opening of the smelter in 1848 the more uncertain coal supply situation would have been aggravated by shortages of shipping.

⁶⁹ *SAPP*, no. 108, 'Railways and Tramways', 1857, evidence The Hon. H. Ayers, minute 2000.

⁷⁰ Ledger 1, BRG 30, pp. 12-22, 111-116, SLSA.

⁷¹ H. Ayers to Mr. M.H. Furniss, 19 March 1873, BRG 22, 961, *Letters to SAMA Officials*, SLSA; *Ibid.*, H. Ayers to Capt'n Sanders, 21 May 1873, no. 26.

⁷² *Ibid.*

⁷³ Cumming, *Notes on the Burra Mine*, p. 42; Bannear & Annear, *Burra Smelting Works*, p. 49.

⁷⁴ See for example, H. Ayers to M.H. Furniss, 28 May 1872, BRG 22, 961, no. 38, SLSA; *Ibid.*, 29 May 1872, no. 39; *Ibid.*, 3 June 1872, no. 42; *Ibid.*, 12 June 1872, no. 45; *Ibid.*, 25 March 1873, no. 97. As late as 1875, when referring to coal versus wood, Ayers stated that 'the advantages of wood as a fuel are undoubted, See, *Ibid.*, H. Ayers to Capt'n. Sanders, 16 April 1875, no. 120.

⁷⁵ In 1849 an agreement was made between the PCC and SAMA that for firewood and timber, SAMA would abide by the rates set by the PCC. See H. Ayers to Wm. Hanson Esq., 3 December 1854, no. 121, BRG 22, 960, SLSA. As an example of their cooperation SAMA instructed teamsters to divert firewood supplies they had ordered to the E&ACC as their stocks had declined. See, 3 March 1866, no. 1251, BRG 22, 966, *Superintendent's Letter Book, 16 December 1856 to 2 February 1855*, SLSA.

⁷⁶ For the sources of supply see Davies, 'Bullocks and Rail'.

⁷⁷ For details see, Davies, 'Copper Connections'.

⁷⁸ H. Ayers to Capt'n. Henry Roach, 21 March 1867, no. 1228, BRG 22, 961, SLSA; W.H. Challoner to H. Ayers, 5 October 1867, no. 1360, BRG 22, 966 (SAMA, Superintendent's letter books), from W.H. Challoner, SLSA.

⁷⁹ *Ibid.*, M.H. Furniss to H. Ayers, 14 August 1872, no. 73. The differential of two shillings per ton between dry and green wood was generally adopted.

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- ⁸⁰ *SAPP*, no. 97, 'Gawler Railway Extension Bill' 1857, evidence Mr. James Hamilton, Manager of the English & Australian Copper Co., minutes 846-49.
- ⁸¹ H. Ayers to J.B. Graham, 23 November 1854, PRG 100, SLSA; see also, *Ibid.*, 31 May 1855, no. 53, and 21 May 1857, no. 60.
- ⁸² Bannear & Annear, *Burra Smelting Works*, p. 55.
- ⁸³ H. Ayers to J.B. Graham, 11 June 1856, no. 56, PRG 100, SLSA.
- ⁸⁴ Bannear & Annear, *Burra Smelting Works*, p. 51; Cumming, *Notes on the Burra Mine*, pp. 46-47.
- ⁸⁵ See Davies, 'Copper Connections', especially p. 56.
- ⁸⁶ Bannear & Annear, *Burra Smelting Works*, p. 53.
- ⁸⁷ Henry Brown, 'The copper Industry of South Australia – An Economic Study', MA thesis, Adelaide University, 1937, revised 1960, pp. 69-70; See also similar arguments in *The Adelaide Observer* (Supplement), 18 May 1861.
- ⁸⁸ *SAPP*, no. 144, 1860, 'Report on Mineral Lease Claims near Wallaroo'; Wallaroo Mines Accounts Book 1860-61, p. 9, BRG 33, SLSA.
- ⁸⁹ Bannear & Annear, *Burra Smelting Works*, p. 57.
- ⁹⁰ *SAPP*, no. 97, 'Gawler Railway Extension Bill' 1857, evidence Mr. James Hamilton, Manager of the English & Australian Copper Co., minute 847.
- ⁹¹ *The Adelaide Observer* (Supplement), 18 May 1861.
- ⁹² *The Mining Journal*, 20 July 1861.
- ⁹³ Journal 4, December 1863, p. 538, BRG 30, SLSA.
- ⁹⁴ See for example, H. Ayers to Wm. Henderson, London, 22 January 1862, p. 192, BRG 22, 960, SLSA, where SAMA expressed their dissatisfaction with E&ACCs terms.
- ⁹⁵ Chaput, 'The Burra Burra Question', p. 71.
- ⁹⁶ Ledger 3, BRG 30, pp. 47, 52-53, SLSA.
- ⁹⁷ *SAPP*, no. 25, 'Report on Public Works, 1862 – report on Railways (Traffic Branch)', p. 21.
- ⁹⁸ Journal, June 1861, p. 548, BRG 30, SLSA.
- ⁹⁹ 10 May 1871, p. 244, BRG 957, SLSA.