# The Evolution of Early Copper Smelting Technology in Australia[1]

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**PART II**

## Case Study 3: Mount Lyell

Most economic geologists have heard of the Mount Read Volcanics of north-western Tasmania, a complex region hosting major deposits of tin, gold, silver-lead, zinc, iron and copper. The greatest mineral deposit of all in these wild rainforest-covered ranges was discovered by prospectors at Mount Lyell in 1886. They were delighted to find a gold mine, but it was merely the tip of an iceberg; their gold was the alluvial deposit from the gossan cap of an enormous gold-copper orebody.

Development of a large mineral deposit in remote and rugged country takes capital, skill and confidence, and it was 1891 before a company was formed to take the Mount Lyell copper discovery in hand. Even then it had little success in raising finance, and the mine lived for its first few years on a fortuitous shoot of silver, until copper output from the smelters during the great copper boom caused its share price to soar.[1]

It was recognised from the outset that the Mount Lyell orebody was very large, but that it was highly pyritic and by no means rich, mostly under 10 percent copper. It was in every way the antithesis of Burra. The copper mines of North America were demonstrating their expertise in dealing with ores of this kind, and the beginnings of Mount Lyell demonstrate the shift of Australian copper smelting technology from Europe to North America. The company's first adviser was Herman Schlapp, German-born but experienced in North America. The manager of the Mount Lyell smelters from 1896 to 1922 was Robert Carl Sticht, likewise a graduate of Clausthal in Germany but with years of experience in the American West. And the most influential adviser was Edward Dyer Peters, a graduate of Freiberg Bergakademie, leading figure in North American copper smelting and a conspicuous advocate of blast furnaces.[2] He was contracted for six months to conduct trials on the site before smelting commenced and maintained a close collaboration with Sticht during the several years it took to perfect the pyritic process.

The choice of technology at Mount Lyell was never in doubt, and American precedents figured strongly in the design of the new plant.[3] The smelters opened at Queenstown at the foot of the mountain in 1896 with the crushed ore being charged into a battery of eleven waterjacket blast furnaces similar in design to those at Great Falls, Montana. The matte went straight to Stallmann converters like those in the Anaconda smelters at Butte, and the blister copper was railed to the coast and shipped for refining. There is no doubting Sticht's skill in dealing with this difficult ore; by increasing the height of the furnaces, using a powerful cold air blast and a large and carefully controlled charge of silica flux, he was able to smelt by pyritic or partial pyritic methods as economic circumstances demanded.[4]

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[1] Based on a paper presented at the Third International Mining History Conference, Colorado School of Mines, Golden, Colorado, 6 June 1994.

The legacy of this brilliant technological achievement was to last twenty-six years. Smelting at Mount Lyell continued under Sticht's supervision and by his methods until 1922, when depression in the world copper market brought an end to both. To reduce fuel costs even further, the company adopted fine grinding and flotation to concentrate the ore before smelting by conventional methods. This remained the practice at Mount Lyell until 1969 when smelting ceased altogether. After that the concentrate was trucked and railed to the port of Burnie and shipped to Japan (and more recently India) for smelting.

**Photograph 1:** *Mount Lyell smelters in 1964*.

Source: Photo courtesy Don Perkin.

Repeated redevelopment of the mine's surface workings in its cramped valley site since 1922, the construction of the concentration plant and a later refinery, and later remodelling or demolition of both, has left very little physical legacy of Sticht's smelter plant. The only identifiable components are masonry flues running up the hillsides above the smelter site, a heap of granulated slag which the company is trying to revegetate, and a single brick smokestack.

The scale of the Mount Lyell operation outstripped every other copper smelter in Australia until Mount Isa commenced large-scale copper production in 1953. Mount Lyell has produced over 1.5 million tons of copper metal to the present, of which roughly a million tons was smelted at the mine. The Mount Lyell Mining and Railway Company closed in December 1994, a little over a century after it was formed. The mine was operated for a time by Copper Mines of Tasmania, which was acquired by Sterlite Industries (India) in 2000.

**Case Study 4: Crotty**

The town of Crotty and its associated copper smelter were located only 20km from Queenstown and the Mount Lyell mine on Tasmania's west coast. Both smelted the same ores for the same market, and yet their histories could not be more different. The story of Crotty is a list of poor management decisions on the part of the founder and the directors: wrong location, unsuitable technology, and duplication of infrastructure. These led to the complete failure of the enterprise within a few years, and the incorporation of the company into Mount Lyell.[5]

Irish miner James Crotty had been an early prospector at Mount Lyell from 1884, and owned a 30 percent share in the Iron Blow orebody. But he was never a team player, and his ideas to develop the mine were repeatedly frustrated by other directors. When the syndicate was forced to bring in investors to float the company and capitalise the mine in 1892, Crotty was allotted only 3 percent of the shares, and this began his feud with the Mount Lyell Mining Company. Crotty decided to go it alone.

In 1896 while Sticht was building his smelter, Crotty returned to England and set about maligning his enemies and raising the capital for another mine - the North Lyell - to which he had already obtained the leases. He raised over £600,000 capital to build a long railway from the mine to a smelter plant located amid abundant firewood supplies, and then to a port on the edge of Macquarie Harbour. Every element of this infrastructure duplicated that of the Mount Lyell company, whereas a more sensible arrangement would have been to share. Although he knew of the success of Peters and Sticht's experiments, Crotty decided to build reverberatory furnaces fired by wood. This was partly because he had faith that the carbonate ores of the Iron Blow would continue at depth, and he did not want to rely on his competitors for supplies of pyritic ore. Crotty died in 1898 as the survey of his railway line was underway, but his co-directors respected his wishes not to treat with the Mount Lyell Company. The result was that everything the North Lyell company attempted ended in failure.

John Stewart MacArthur of Glasgow, co-inventor of the cyanide process for gold extraction, designed the reverberatory furnaces. Despite his reputation as a chemist, he was a woeful designer of treatment plants.[6] The Crotty smelter was simply a disaster. MacArthur believed that the furnaces would be economical on both fuel and flux; they were neither. The local firewood would not reach temperature, and the company had to import coal. The decision to use reverberatory furnaces meant that a large treatment mill had to be built to crush and concentrate the ore before smelting. Hasty and cheap construction practices resulted in furnace collapses. When they were coaxed into operation in September 1901 the furnaces failed to smelt the ore. The North Lyell Company had to negotiate with the Mount Lyell Company to temporarily smelt their ore while repairs were effected. As a trade they paid in ore, which happened to blend perfectly with the Mount Lyell ore and so reduced that company's smelting costs.

The ore coming from the Iron Blow was much higher in sulphides than had been expected, and North Lyell ordered six converters to process the matte after smelting. These were probably the next converters in Australia after Mount Lyell's: they were ordered from Webster, Camp & Lane Company of Ohio in February 1901 and arrived a year later. The blowers were inadequate, and the smelter hands struggled with the intransigence of the unfamiliar converters; only one was ever installed and that was never used. By the time of its installation the Company had decided to cut its losses and install blast furnaces after all, the decision Peters and Sticht had made five years earlier.

Five second-hand waterjacket blast furnaces were purchased from Port Pirie in South Australia, where they had been used for smelting lead. They too had teething problems, and were only half the size of Sticht's furnaces. Although they were eventually smelting successfully by the latter part of 1902, the company was in so much financial strife that closure was inevitable. By that time Sticht had achieved pyritic smelting while Crotty was still importing trainloads of coke, and the contrast between the two companies' affairs could not have been starker. The Mount Lyell Company took over all the North Lyell assets and liabilities at the end of May 1903. The smelters and the town of Crotty were closed immediately, and all Mount Lyell ore was henceforth treated at Queenstown.

By 1991 the Crotty site was covered by regrowth forest. There were low structural or foundation remains of all the major buildings still extant. The multi-level concentration mill site on the side of a hill had intact engine beds, floors and retaining walls; the flue from the blast furnaces to the main chimney site was still discernible although it had been robbed of bricks, as had the reverberatory furnaces themselves. These were shallow, brick-littered depressions with some buckstays and iron bars still extant. The chimney foundations and parts of the flues are still intact. On the blast furnace site the remains of three blast furnaces were still extant. The remains include parts of the cast iron waterjackets, sections of air blast mains, iron buckstays and numerous bricks. Associated foundations for the blowers, motors and generators were located nearby, as was a slag dump. In 1992 the whole of the valley in which the Crotty smelter and town were located was flooded as part of a hydro-electricity generation scheme, and the site is now submerged under the King River dam.[7]

**Case Study 5: Chillagoe**

Chillagoe is located in far North Queensland, in the hinterland to the west of Cairns. Although in operation for over four decades, the Chillagoe smelters never actually recorded a profit in any year. Initial over-estimation of ore reserves, poor knowledge of the geology of the area, the distance from the mines and speculation on the part of its early promoters, all combined to make the first phase a failure. When later taken over by the government, a scandal involving politicians of the day, poor world copper prices and aging plant were the key elements of the second phase failure. Government subsidies however meant that through linkage and multiplier effects, the operation of the smelters kept thousands of people employed in the mines, on the railways and on the docks throughout the Cairns region.[8]

Copper and silver-lead deposits were discovered in the area in 1888 and the Chillagoe Proprietary Limited company was floated in Melbourne in 1897. In 1898 it was reconstructed as Chillagoe Railways and Mines Limited with estimated ore reserves of 500,000 tons. Construction of the smelters at Chillagoe commenced in July 1900 and by March 1901 the extension of the railway from Mareeba was completed. The location of the smelters proved to be unfortunate; trying to provide a central facility for a large district meant that freight costs were high on all ores. By the time two waterjacket blast furnaces were blown-in in September, the ore reserves had been revised downward to 176,000 tons. By November of that year the directors were selling their shares and the ore reserves were again revised downward to 95,000 tons. The smelters closed after an expenditure of £600,000 and the production of a mere 367 tons of copper. It was a bad start.

The company was reconstructed a second time in February 1902 as the New Chillagoe Railways and Mines Limited and the smelters re-opened in October. Extensive problems with the main plant necessitated re-evaluation of the production processes and much experimentation was undertaken. But the difficult geology and unknown nature of the mineralisation led to intractable metallurgical problems. The company's mines produced some lead and copper carbonate ores, which were relatively easy to smelt, but in a theme becoming familiar in Australian smelting, the sulphides were presenting recurring problems. And in a situation peculiar to Chillagoe, some of the ores from Mungana had copper and lead sulphides mixed together, untreatable by orthodox methods. An entirely new plant was later to be installed to deal with these. As had happened at Crotty, a converter plant was introduced in 1904 as a remedial measure to convert copper matte to blister copper, but inadequate blowers limited the success of this modification until they were replaced in 1908.

Over the next few years Chillagoe tried to settle into a regular smelting cycle, but production stayed low because ore deliveries from outside suppliers were erratic, and the company didn't have sufficient supply from its own mines to run the furnaces to capacity. The idea behind the Chillagoe smelters had always been to service all the mines in the region. Deciding its catchment was inadequate, the company raised debentures in London to build a railway to the Etheridge gold and copper field some 200km to the south. When the railway opened to Forsayth in 1910, the Chillagoe company owned 394km of track, one of the longest private rail networks in Australia.

Simultaneously there was drastic redevelopment to tackle the pyrite problem. The company built a new plant at Chillagoe to treat the lead sulphide ores, consisting of Edwards roasters and a Huntington-Heberlein plant. The copper plant was also upgraded by the addition of another blast furnace, four new converters and more powerful blowers. By the end of 1908 all this plant had been built and was operating fairly successfully; in that year Chillagoe produced its highest output of 6,000 tons of lead and over 2,000 of copper. But this was achieved at the price of enormously increased debt, at a time of falling metal prices.

Despite these innovations, things continued to go drastically wrong for the Chillagoe company. Over the next six years world copper prices continued falling, one of the major mines supplying lead ore closed due to a massive rock fall and underground fire, a newly-organised union pushed for better wages and conditions, a fire destroyed the furnace and converter sheds and a major rock slide cut off coke supplies. The company was reconstructed yet again in 1913 but by March 1914 it finally collapsed. The closure of the central smelters also closed all the mines of the district, as they had no market for their products.

The smelters remained closed for the duration of the First World War. During this time world copper prices reached extremely high levels, and Labor politicians were seeking ways for the State to reopen the mines. After the election of a Labor government in Queensland in 1915 and protracted negotiations with the company in Melbourne, the debenture-holders in London, and the Liberal-dominated upper house, the Chillagoe and Etheridge Railways Act passed through parliament. The government was to buy the smelters and railways for £450,000 and operate them as State enterprises. Ironically, the Act received assent in 1918, just four days after the war was over and commodity prices were on the way down.

The State reconditioned the Chillagoe smelters and re-commenced operations in January 1920. They ran steadily for seven years, employing about 750 men. This run was checked by a major political controversy known as the Mungana Scandal that involved the smelters manager, two Labor premiers of Queensland, and other politicians and public servants. The crux of the issue was the fraudulent sale of the Mungana mines to the State in 1922, but there was also an ongoing history of corrupt dealings surrounding the State enterprises, involving the smelters' ore buying and materials supply practices. Exposure of the scandal led to a change of government, resulting in a Royal Commission in 1930 and the ruin of several political careers.[9]

**Photograph 2:** *Chillagoe smelter ruins from the air, 2004. Blast furnaces stack at left, boiler stack at lower right, and lead roasters stack in background.*

Source: Photo by Peter Bell

The Chillagoe smelters were closed for two and a half years. They re-opened in October 1929 and worked until 1943. Although commodity prices continued to fall, the State kept the smelters going conservatively on a subsidised basis to create work in the depressed mining districts. There was no physical change to smelter plant, and virtually no money had been spent at Chillagoe since the reconditioning at the commencement of State ownership in 1919. Lead smelting ceased in 1933, but production of copper and gold continued. By the 1930s, there were very few mines still operating in the Chillagoe-Mungana district. Much of Chillagoe's ore was being railed improbable distances from the Cloncurry district, which had no closer smelter. The entry of Japan into the Second World War prompted a Commonwealth government review of all base metal mining operations in Australia. Chillagoe was rundown and unviable, and the smelter was ordered to close in July 1943, when Mount Isa began to smelt copper for the Cloncurry miners. At Chillagoe, a small team kept the smelters going on a care and maintenance basis until 1949 and then all plant was auctioned or otherwise removed in 1950. Between 1900 and 1950, the Chillagoe smelters probably lost their two owners, the Chillagoe company and the Queensland government, a total of between four and five million pounds. The construction of the smelters had simply been a mistake.

The archaeological legacy of the site is important and impressive. The most obvious features are the three large brick chimneys (from the lead roaster plant, the boiler plant and the blast furnaces), with the long main smelter flue running up a hillside, and a slag dump containing over one million tons of slag. There are the remnants of one blast furnace still in situ and reasonably intact, and the site is littered with various pieces of plant and machinery: air blast mains, flues, converter vessels, tanks, crushing rolls, parts of the Huntington-Heberlein kettles. To the trained eye the remnants of all the main processes used there are visible and have been recorded in a detailed site survey. The archaeological survey also revealed new information about the site, explaining how it developed through time and how each of the processes contributed to the functioning of the place.

Both the Chillagoe company and the State administration had for different reasons, destroyed most of their records of the Chillagoe smelters. The scanty nature of available historical information presented a confused picture of the development and operation of the site. The historical record for instance, states that there were six blast furnaces operational there and the physical record indicates provision for six - but one of these was clearly never used. The archaeological survey revealed that the reason for this was that the enlarged blowing plant was installed in that location. Likewise the chronology and relationship between the Edwards roasters, the Huntington-Heberlein plant and the Dwight Lloyd sintering plant - all of which were installed in the same area - were difficult to understand. Careful archaeological surveying and recording identified the remains of each plant and made new discoveries about the technology of each. For example, the Edwards roasters were found to be of two different types - single and duplex. Only the duplex roasters were reported in the historical documentation and it seems that the single roasters were trial prototypes. Similarly the type of Dwight Lloyd plant was also identified from the three types available (straight line, drum or horizontal machines); the plant in fact utilised two straightline machines. The site is now administered by the Queensland Parks and Wildlife Service as part of the Chillagoe-Mungana Caves National Park, and is one of the more intact and interesting historic smelter sites of Australia.

**Case Study 6: The Peake**

The Peake is located in the arid far north of South Australia and became notable as the location of one of the repeater stations on the Overland Telegraph Line built across Australia from south to north in the early 1870s. Gold was discovered in the Davenport and Denison Ranges nearby about the same time, and small finds of copper and silver were subsequently reported. The Oodnadatta railway was built only a few miles west of the site in 1889.[10]

The site is of interest as a case study of a small, isolated, portable and short-lived copper smelting operation which is quite well historically documented and which has relatively undisturbed physical remains. The venture failed, as it was essentially a speculative one. The small, high grade ore deposit was enough to elicit quick and positive early results, which seduced the Melbourne market and made the venture look attractive. In fact, it was only the proximity of the railway that made the prospect even marginally viable. Remoteness, insufficient ore reserves, poor management and inappropriate technology combined to doom the subsequent smelting operation.

In 1888, while the railway was being built from Marree to Coward Springs, copper ore was found not far from The Peake telegraph station. Over the next ten years, a number of small mines were opened, including the Peake Hill, Denison, Warrina and Copper Top. In 1899 with the price of copper booming, the region was thoroughly prospected and the Copper Top Proprietary Mining Company was floated on the Melbourne Stock Exchange. Initial assays showed yields of 20-60 percent copper with small amounts of gold and silver. The company was over-subscribed within 48 hours, raising £9,375 capital of a nominal £50,000, with 25,000 shares being held in reserve.

Work commenced in March 1900. The Company soon amalgamated with the other mines in the area to become the Amalgamated Copper Top Proprietary Mining Company. They proposed to build a smelter within sight of the Telegraph Station. No expense was to be spared; the company announced that they expected eventually to employ 3,000 men in the mines, and for their smelting campaign they would import a blast furnace from the USA and the best coke from England. By mid-May construction and development work were well advanced - earthworks and roadworks were completed; a store-room, engine room, assay office and smelt shed erected; and a bore sunk which would be capable of supplying the necessary 24,000 gallons of water per day to the blast furnace. Details of the proposed plant are noteworthy. All of the major plant was to be of American origin: a circular Fraser and Chalmers water jacket blast furnace, a Worthington piston pump and a Green's blower.

Although the blast furnace was installed by the end of August 1900, it was not blown-in until nearly two years later. The reasons for this delay are not clear in the reports of shareholders meetings; it appears though, that while the directors kept giving glowing reports, not much was actually happening at the site. Some ore was being stockpiled but just how much seems open to conjecture. The directors stated in July 1900 that there were at least 1,000 tons at the mine, but an independent report obtained by some shareholders stated that there were less than 200.[11]

This languid state of affairs continued until the blast furnace was blown-in in May 1902. The result was disastrous; the furnace could not be made to operate satisfactorily; it would run for six hours or so and then cool down. All the available fuel was being consumed before the smelting temperature of the ore was achieved. The mine was closed temporarily until a new metallurgist was found. Modifications were made to the plant and eventually some ore was smelted in small parcels during 1903, although the details remained vague.

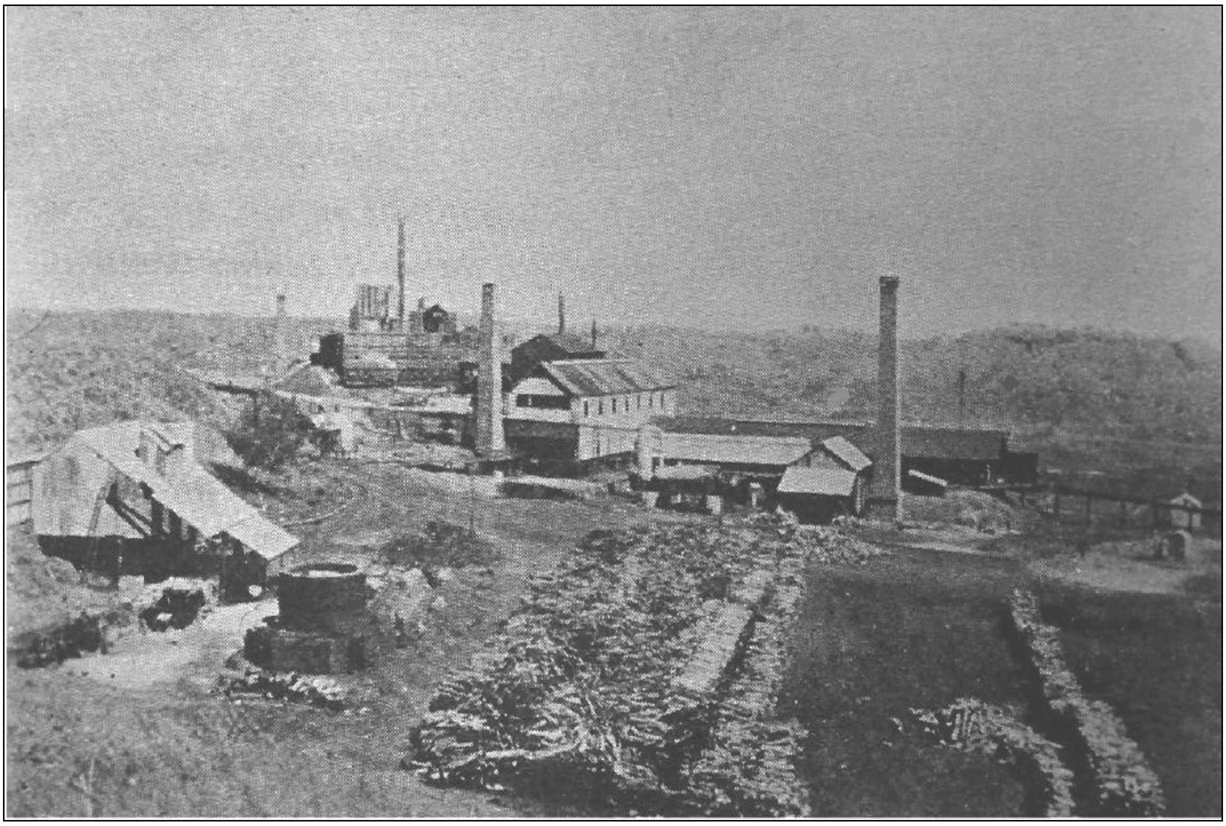
At the shareholders meeting of January 1904, the directors recommended winding up the company. The Copper Top enterprise had been a catastrophe; costs in the outback site were stupendous, there was little ore - the best of it proved to be less than 3 percent copper - and the furnace had never worked properly. Even the mine manager referred to the mine as 'a real duffer'.[12] The plant had only processed 250 tons of copper ore and concentrate for an average metal content of just 4 percent. The smelter was dismantled in 1904 and the Melbourne investors lost their money.

The archaeological legacy of the mine is interesting. Newspaper reports indicate the mine was stripped of all machinery and certainly there is nothing left of the major equipment items. Some remnant pieces of overhead drive shafts and belt pulleys embossed 'Bennett, Meadville PA' confirm the historical evidence indicating that the major equipment was American made. There is evidence of the location of the furnace and at least one crusher. The major surviving evidence consists of two mine shafts, the earth and road works, dry-laid and lime mortared walls, the ruins of the assay house and another house (perhaps the mine manager's) and a small quantity of poured and broken slag. The amount of slag is consistent with the historical record that only about ten tons of copper metal was smelted there.

**Case Study 7: Mount Elliott**

Copper ore deposits had been known at many places in the far north-west of Queensland since the 1860s, but in such a remote and arid region, little was done to develop them until provision of some infrastructure had begun to lower costs. It was the early twentieth century before copper smelting began in the district on a serious scale. In 1906 the Queensland government announced it would extend the Great Northern Railway to the town of Cloncurry, about 800km from the east coast. The copper price was high, a number of companies were formed, and the Cloncurry copper boom was on.[13]

**Photograph 3:** *Mount Elliott smelters in 1911. Note scale of firewood stocks.*



Source: *Queensland Government Mining Journal,* 15 November 1911.

Mount Elliott Limited was floated in Melbourne in 1906, but soon after reconstructed as a London company. Mining commenced on the Mount Elliott outcrop in 1907, and a smelter was commissioned by 1909, consisting of a 100 ton waterjacket blast furnace and barrel converters which the first manager, William Corbould, described as 'purchased secondhand from goodness knows where', and a 'collection of worn-out junk'.[14] There may have been an element of professional bias in Corbould's opinions, for he had recently built and managed the reverberatories at Burraga in New South Wales, and was regarded as the principal Australian authority on reverberatory practice.[15]

**Photograph 4:** *Mount Elliott smelter ruins from the same viewpoint in 1992. The furnace and converter levels can be seen at right.*

Source: Photo by Peter Bell

The plant at Mount Elliott was nearly identical to the copper-smelting part of the Chillagoe works, which is not surprising as the consulting engineer who designed it was Ernest Weinberg, who had been chief metallurgist to the Chillagoe company. It certainly seems to have been poorly designed and badly built, as Corbould complained:

> Apart from the poor condition of the plant its layout was all wrong. To charge the converters with molten matte from the blast-furnace there was a cast-iron launder channel having two beastly bends in it so that most of the matte would end up on the ground. Slowing it down so that it could take the bends would mean that it would freeze before reaching the converters.[16]

The choice of waterjacket furnaces for Mount Elliott seems odd, for the ore was not particularly high in sulphides and would probably have responded well to reverberatory smelting. Donald Chaput has written a review of Weinberg's career which gives him more credit for successful smelter design than these remarks imply, however the poor performance of both the Chillagoe and Mount Elliott smelters raises some questions.[17]

Corbould redesigned the smelter and ordered new plant from Walkers' Maryborough foundry, but retained the waterjacket/converter process. His new plant was blown in when the railway arrived at Mount Elliott in 1910. Like Chillagoe, Mount Elliott could not produce good blister, but whether this was the result of bad fluxing, insufficient air blast to the converters or other causes is impossible to tell. In 1916 the company built a reverberatory refinery on the coast near the Bowen coalfield in an attempt to overcome the problem.

In 1914-15 the Mount Elliott smelter underwent a change of role. The Mount Elliott mine closed because of declining ore grades, and the smelter began taking ore from Mount Cuthbert and other mines in the Cloncurry district. The railway, ore bins and ore handling plant were all rebuilt to allow the smelter to accommodate the new feedstock. Despite reliance on firewood as fuel, and the many Heath Robinson improvisations he had made to an initially poorly designed plant, Corbould was able to run the smelter efficiently on ore grades as low as 4 percent.

Mount Elliott closed in 1919 after the copper price fell. The entire Cloncurry copper field was dependent on First World War metal prices, and folded up when the war ended. The Mount Elliott smelter remained more or less intact for twenty-four years, when Mount Isa began smelting copper for the new war effort at the command of the Controller of Mineral Production. Mount Elliott was torn apart in 1943 by Mount Isa engineers who built their new wartime smelters out of the wreckage of the old Cloncurry copper industry.[18]

The Mount Elliott site today is very similar in some respects to the copper smelter at Chillagoe: similar layout and nearly identical plant items point to their shared origins. However, whereas the Chillagoe copper works changed very little from 1901 to 1943, Mount Elliott was twice subject to major rebuilding and changes of mind while the work was underway, and this is evident in its fabric. A scatter of minor equipment on the site dates from the hasty dismantling of useful plant in 1943. Many of the standing structures are of shoddy unreinforced mass concrete, a legacy of First World War material shortages and now in very poor condition.[19]

## The Sites Today

This is to some extent an archaeological as well as a historical paper, and much of its evidence is drawn from site surveys on the smelter remains. The condition of historic copper smelter sites today is extremely variable. It depends not so much on their establishment and development while in operation, but more on the processes of abandonment, re-use, and removal of elements of the sites for use elsewhere. The Mount Lyell smelter site has remained continuously in use for other industrial purposes since, so little survives of the historic plant. Others such as Mount Elliott and Chillagoe remained intact in remote areas until relatively recently - 1943 and 1950 respectively - and were then systematically dismantled to remove their useful parts, leaving the rest to decay. Others such as Burra and Kapunda were abandoned over a century ago in close proximity to towns, and their sites have been scavenged by generations of residents in search of building materials. One of the most impressively picked over is Kapunda, where not a stone remains. Even the slag is gone, taken for use as building stone in a town where the local sandstone is very soft.

## Conclusion

When copper was first discovered in Australia the world leaders in copper smelting technology were Germany and Wales. After a few experiments with both techniques, there was almost universal adoption in Australia of the Welsh reverberatory in preference to the German cupola. The reasons for this may have been no better than the fortuitous circumstance that the Welsh process happened to be very well suited to the rich carbonate ores that characterised most early copper discoveries. As time passed, the copper industry in Australia found it had to mine lower-grade deposits of sulphide ore instead of vainly searching for another Burra. The Welsh furnaces did not always deal effectively with these more demanding ore-bodies.

Successful techniques for smelting these ores had been developed in North America by the refinement of German blast furnace techniques and English iron converting methods. Thus by the 1890s, Australian metallurgists were looking to the USA rather than to Europe for their technology. In 1870 the manager of a copper smelter in Australia was most likely to be a white-bearded Welshman who learned the trade as an apprentice in Swansea. By 1910 an Australian copper-smelting expert was far more likely to be a young American with a German surname and an engineering diploma from Arizona or Michigan. The physical forms of the smelters evolved from low brick reverberatories to tall steel blast furnaces, accompanied by the new technologies of roasters, converters and electrolytic refineries. The smelter ruins today reflect this economic and cultural transition, as Australian copper miners looked outside the British Empire to learn from the wider world.

**Endnotes**

[1] This account of the Mount Lyell smelters is based chiefly on G. Blainey, *The Peaks of Lyell*, Melbourne University Press, Carlton, 1959, and his later publication, *The Rush that Never Ended: a history of Australian mining,* Melbourne University Press, Carlton, 1969.

[2] E.D. Peters, *Modern Copper Smelting,* Engineering and Mining Journal, New York, 1906*;* E.D. Peters, *The Practice of Copper Smelting,* McGraw Hill, New York, 1911.

[3] H.O. Hofman, *Metallurgy of Copper*, McGraw Hill, New York, 1914*,* pp.152-156, 301.

[4] Peters, *The Practice of Copper Smelting,* p. 210.

[5] Blainey, *The Peaks of Lyell*.

[6] *Ibid.,* pp. 145 & 156, says that MacArthur's poor furnace design at Crotty destroyed his own reputation and 'ultimately wrecked' the North Lyell Company.

[7] J.P. McCarthy, Phase 2 Archaeological Investigation of the King River Power Development Scheme, unpublished report for Tasmanian Hydro-Electric Commission, 1991.

[8] Allom Lovell Marquis-Kyle Architects & Austral Archaeology, Chillagoe Smelter Conservation Plan, unpublished report for Queensland Department of Environment and Heritage, 1993.

[9] K.H. Kennedy, *The Mungana Affair: state mining and political corruption in the 1920s*, University of Queensland Press, St Lucia, 1978.

[10] L. Brasse, *et al*, The Peake Historic Site, unpublished report for South Australian Department of Environment and Planning, 1987.

[11] *Advertiser,* 31 July 1900.

[12] *Ibid.,* 19 January 1904.

[13] For Mount Elliott see K.H. Kennedy, 'The Cloncurry Copper Companies', in K.H. Kennedy (ed.), *Readings in North Queensland Mining History Volume One*, James Cook University of North Queensland, 1980, pp. 221-250; I. Hore-Lacy (ed), *Broken Hill to Mount Isa: the mining odyssey of W.H. Corbould*, Hyland, Melbourne, 1981.

[14] *Ibid.,* p. 148.

[15] J.E. Carne, *The Copper-Mining Industry and the Distribution of Copper Ores in New South Wales*, Government Printer, Sydney 1908, pp. 30-36.

[16] Hore-Lacy, *Broken Hill to Mount Isa*, p. 148.

[17] D. Chaput, 'E.A. Weinberg and the Australian Smelting Industry', Proceedings of the Australasian Institute of Mining and Metallurgy *Southern Queensland Conference*, 1985, pp. 143-151.

[18] G. Blainey, *Mines in the Spinifex: the story of Mount Isa Mines,* Angus & Robertson, Sydney, 1970, p. 187.

[19] J. Knight, Mount Elliott Mine and Smelter Site, North West Queensland: a preliminary survey and conservation recommendations, unpublished report for Cyprus Gold Australia Corporation, 1992.

## APPENDIX A

### Smelting Copper at Burra, 1847

What follows is the most detailed description in print of the first copper smelting operation in Australia: it purports to be an eyewitness account of the Dreyers' firing their blast furnace at Burra in mid-October 1847. It was published in London in the *Mining Journal, Railway and Commercial Gazette*, 22 April 1848, p. 199, headed 'From our Correspondent'.

> Adelaide, Oct. 20 .... I was at the mines last week ... I witnessed, amongst other things, the smelting operations which are under the direction of Mr. Dreyer, who has had 22 years' experience in the Hartz Mountains, smelting copper with charcoal; it is a small blast-furnace, of two 10-ft bellows, driven by a pair of horses; it answers very well for an experiment, but cannot succeed with horse-power on a large scale. The ore is first slightly roasted by heaping it on a few logs of wood, and setting fire to it; this is found quite sufficient to drive off the very little sulphur contained in it, and the moisture. The furnace is then charged, adding a little limestone as a flux, and in three hours the copper is run off in the state of black copper; one more smelting produces fine metal. The slag separates perfectly pure from the metal; nothing could be more satisfactory; and it is now certain that, with a steam engine to produce the blast, any quantity of copper, in comparison to the number and size of the furnaces used, can be manufactured at the mine ...

Much of what we know about the Dreyers' furnace comes from this paragraph. However, it reads more like a press release intended for the London newspapers than the account of a genuinely disinterested journalist. Despite the optimistic tone of the article, the matte smelting operation described was the single most successful day in 20 months of experimentation, seven months of it in this same furnace. Far from being the culmination of that effort as the correspondent suggests, it was the final straw for the company directors. They declined to finance further development of the German blast furnace technique, and instead out-sourced their smelting campaign to the Patent Copper Company of Swansea. While the correspondent wrote as though he was witnessing the beginning of a triumphant era of German smelting technology at Burra, he was in fact describing its end.

## APPENDIX B

### Summary of Copper Smelters built in Australia to 1918

This list is not definitive, but has gaps reflecting those in the variety of sources from which it has been compiled. It does not include the multi-purpose custom smelters such as Newcastle, Cockle Creek, Aldershot, Dapto or Port Kembla, nor does it include all the new furnaces installed over time at large works such as Cobar and Wallaroo, except when a change in technology was involved. The reader must be aware that some smelters had more than one name, for example Great Fitzroy was also Mount Chalmers, likewise Hampden and Kuridala, Girofla became Mungana, and Walhalla was the same place as Thomson River. The list is sufficiently comprehensive to give a good overall picture of the types of smelter and their dates of construction and use. The authors are grateful for the assistance of Dr Michael Pearson, Dr Ruth Kerr and Dr Roger Kellaway in the compilation of this list.

| Date built | Place | Type | Last used |
|---|---|---|---|
| 1847 | Burra SA | hot blast furnace | 1847 |
| 1848 | Bremer SA | reverberatory | 1851 |
| 1849 | Yatala SA | hot blast furnace | 1851 |
| | Apoinga SA | reverberatory | 1850 |
| | Kapunda SA | reverberatory | 1866 |
| | Burra SA | reverberatory | 1869 |
| | Hobart Tas | reverberatory | ? |
| | Lane Cove NSW | reverberatory | ? |
| 1850 | Strathalbyn SA | no details | 1850 |
| ? | Copper Hill NSW | blast furnace | ? |
| 1851 | Wheal Barton SA | no details | 1851 |
| | Summerhill NSW | reverberatory | 1858 |
| 1852 | Newcastle NSW | no details | ? |
| 1857 | Scott Creek SA | reverberatory | 1878 |
| 1860 | Bremer SA | reverberatory | 1875 |
| 1861 | Port Adelaide SA | reverberatory | 1912 |
| | Wallaroo SA | reverberatory | 1901 |
| 1862 | New Cornwall SA | reverberatory | 1864 |
| | Copperfield Q | reverberatory | 1867 |
| | Cadia NSW | reverberatory | 1867 |
| 1864 | Blinman SA | reverberatory | 1885 |
| | Kanmantoo SA | no details | 1873 |
| | Copperfield Q | reverberatory | 1877 |
| 1865 | Thomson River Vic | reverberatory | 1881 |
| ? | Nairne Creek SA | no details | 1874 ? |
| 1866 | Spring Creek SA | reverberatory | 1874 |
| 1867 | Tungkillo SA | reverberatory | 1867 ? |
| | Birdwood SA | reverberatory | 1870 |
| | Currowong NSW | reverberatory | 1869 |
| 1868 | Port Waratah NSW | reverberatory | ? |
| 1870 | Sliding Rock SA | reverberatory | 1877 |
| 1871 | Prince Alfred SA | reverberatory | 1874 |
| | Mount Perry Q | reverberatory | ? |
| 1872 | New Lambton NSW | reverberatory | ? |
| ? | Copper Hill NSW | reverberatory | ? |
| ? | Icely NSW | no details | ? |
| | Kariboe Creek Q | reverberatory | ? |
| 1873 | Paringa SA | no details | 1880 |
| | Bolla Bollana SA | reverberatory | 1885 |
| | Mount Clara Q | reverberatory | ? |
| | Tee Bar Q | reverberatory | ? |

**APPENDIX B:** Summary of Copper Smelters (cont'd)

| Date built | Place | Type | Last used |
|---|---|---|---|
| 1874 | Grunthal SA | no details | 1876 |
| ? | Essington NSW | reverberatory | ? |
| 1874 | Mount Coora Q | reverberatory | ? |
| | Blackall Mine Q | reverberatory | ? |
| | Adolphus William Q | reverberatory | ? |
| 1875 | Apsley NSW | reverberatory | 1880 ? |
| | Carangara NSW | reverberatory | 1880 ? |
| | Peelwood NSW | reverberatory | 1879 |
| 1876 | Coombing Park NSW | no details | 1878 ? |
| | Wiseman's Creek NSW | no details | 1880 |
| 1877 | Snowball NSW | reverberatory | 1880 |
| 1879 | Mount Orange Q | reverberatory | ? |
| 1880 | Burraga NSW | reverberatory | 1899 |
| 1881 | Girilambone NSW | reverberatory | 1882 ? |
| 1882 | Blayney NSW | reverberatory | 1898 ? |
| 1883 | Frogmore NSW | reverberatory | 1885 |
| 1885 | Cloncurry Q | waterjacket | 1888 |
| | Cobar NSW | blast (not waterjacket) | 1885 ? |
| | Lake George NSW | blast (not waterjacket) | 1889 |
| 1888 | Mount Boppy NSW | reverberatory | 1891 |
| | Belara NSW | reverberatory | 1907 |
| ? | Copperfield NT | reverberatory | 1888 ? |
| 1889 | Annandale NSW | reverberatory | 1898 |
| 1893 | Cobar NSW | waterjacket | 1901 ? |
| 1894 | Calcifer Q | waterjacket | 1901 |
| 1896 | Mount Lyell Tas | waterjacket (pyritic 1902) | 1969? |
| | Girofla Q | reverberatory | 1901 |
| | Nymagee NSW | waterjacket | 1907 |
| | Gulf Creek NSW | waterjacket & reverberatory | 1907 |
| | Dapto NSW | waterjacket & reverberatory | 1901 ? |
| 1897 | Lake George NSW | waterjacket (partial pyritic) | 1899 ? |
| | Pikedale Q | reverberatory | ? |
| 1898 | Mount Hope NSW | reverberatory | 1902 |
| ? | Frogmore NSW | reverberatory | 1907 ? |
| | Sundown Q | reverberatory | 1900? |
| | Blayney NSW | waterjacket | 1907 ? |
| 1899 | Burraga NSW | waterjacket | 1899 |
| | Mount Cannindah Q | reverberatory | not used |
| | Girilambone NSW | waterjacket | 1899 |
| | Anaconda WA | reverberatory | 1917 |
| 1900 | Mount Garnet Q | waterjacket & reverberatory | 1903 |
| | Mount Chalmers Q | reverberatory | ? |
| | Blayney NSW | waterjacket | ? |
| 1901 | Wallaroo SA | waterjacket | 1926 |
| | Crotty Tas | reverberatory | 1902 |
| | Chillagoe Q | waterjacket | 1943 |
| | Einasleigh Q | waterjacket | 1902 |
| | Mount Perry Q | waterjacket | ? |
| | Wertago NSW | reverberatory | 1901 |
| | Belmore NSW | waterjacket | 1902 |
| | Larry's Hill NSW | reverberatory | 1906 |
| | Cobar NSW | waterjacket ? | ? |
| | Blayney NSW | waterjacket | 1907 ? |
| 1902 | Crotty Tas | waterjacket | 1903 |
| | The Peake SA | waterjacket | 1904 |
| | Burraga NSW | reverberatory | 1906 |
| | Mount Bonnie NT | waterjacket | 1907 |
| | Mount Bulga NSW | waterjacket | 1902 ? |
| 1903 | Palmerston NT | reverberatory | 1903 |

**APPENDIX B:** Summary of Copper Smelters (cont'd)

| Date built | Place | Type | Last used |
|---|---|---|---|
| 1903 | Yam Creek NT | waterjacket & reverberatory | 1906 |
| | Iron Blow NT | waterjacket | 1906 |
| | Yelta SA | waterjacket | 1913 |
| | Mount Rose SA | no details | 1903 ? |
| | Shuttleton NSW | reverberatory | 1907 |
| | Gulf Creek NSW | reverberatory | 1905 |
| | Crowl Creek NSW | reverberatory | ? |
| | Ravensthorpe WA | waterjacket | 1918 |
| | Mount Morgan Q | reverberatory | ? |
| | Glassford Creek Q | reverberatory | ? |
| | Bompa Q | reverberatory | 1905 |
| | Running River Q | waterjacket | 1904 |
| 1904 | Daly River NT | reverberatory | 1909 |
| | Queen Bee NSW | reverberatory | 1908 ? |
| | Blinman SA | waterjacket | 1908 |
| | O.K. Q | waterjacket | 1910 |
| | Mount Molloy Q | waterjacket | 1908 |
| ? | Gabanintha WA | no details | ? |
| 1905 | Mount Gunson SA | reverberatory | 1905 ? |
| | Belmore NSW | reverberatory | 1907 |
| 1906 | Bundarra NSW | reverberatory | 1907 |
| | Burraga NSW | reverberatory | 1909 ? |
| | Cangai NSW | reverberatory | ? |
| | Great Australian Q | waterjacket | ? |
| | Mount Morgan Q | waterjacket | 1914 |
| | Mount Cannindah Q | reverberatory | 1907 |
| | Mount Hector Q | waterjacket | 1908 |
| | Glassford Creek Q | waterjacket | ? |
| | Black Snake Q | waterjacket & reverberatory | 1907? |
| ? | Carrington Q | reverberatory | 1907? |
| 1907 | Queen Bee NSW | waterjacket | 1908 ? |
| | Mount Royal NSW | reverberatory | ? |
| | Mountain Run NSW | waterjacket | 1907 |
| | Mount Everest NSW | waterjacket | 1908 |
| | Peak Downs Q | waterjacket | 1907 |
| | Mount Perry Q | waterjacket | ? |
| | Mount Hector Q | waterjacket | ? |
| 1908 | Blayney NSW | waterjacket & reverberatory | ? |
| | Port Kembla NSW | reverberatory | ? |
| | Gulf Creek NSW | waterjacket | ? |
| | Bogan River NSW | reverberatory | ? |
| | Thomson River Vic | waterjacket | 1909 |
| | Mount Chalmers Q | waterjacket | ? |
| ? | Mount Orange Q | reverberatory | 1908? |
| 1909 | Yudnamutana SA | waterjacket | 1910 |
| ? | Whim Creek WA | no details | 1914? |
| 1910 | Mount Elliott Q | waterjacket | 1919 |
| | Waroo Q | reverberatory | 1911 |
| 1911 | Cardross Q | waterjacket | 1916 |
| | Kuridala Q | waterjacket | 1920 |
| | Mount Flora Q | waterjacket | 1913? |
| ? | Duck Creek Q | no details | ? |
| ? | Longara Q | no details | ? |
| 1913 | Iron Blow NT | reverberatory ? | 1913 |
| 1914 | Mount Morgan Q | waterjacket | 1931 ? |
| 1915 | Corella Q | waterjacket | 1917 |
| 1916 | Bowen Q | reverberatory refinery | 1918 |
| 1917 | Mount Cuthbert Q | waterjacket | 1920 |