REPORT ON THE ARCHAEOLOGICAL EXCAVATION OF SMELTER NO. 1, OLD CADIA ROAD, CADIA, N.S.W.

Volume 1.

Edward Higginbotham,
MA (Cambridge), PhD (Sydney), MAACAI.

EDWARD HIGGINBOTHAM & ASSOCIATES PTY LTD.

Archaeology, History & Heritage.

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MA (Cambridge), PhD (Sydney), MAACAI.
EDWARD HIGGINBOTHAM & ASSOCIATES PTY LTD
140 Smith Street
SUMMER HILL, NSW 2130.
PO Box 97
HABERFIELD, NSW 2045.
Phone. (02) 9716-5154
Fax. (02) 9716-8547.

For
Cadia Holdings Pty Limited.

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CONTENTS.

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Heritage Office: Ms. Caitlin Allen.

Assistance in research: Associate Professor R Ian Jack, University of Sydney.

GLOSSARY OF TERMS.

Air, wind or draught furnace	All names for reverberatory furnaces.
Ash-pit	The ash-pit is located behind or to the side of the fire-box and is used to rake out ashes after smelting is completed.
Buckstay	A section of iron bar, usually I section, used to support the sides of the furnace and held in place by tie-rods. Buckstays can also be of timber.
Conker plate	The conker plate was located in the fire bridge and went from one side to the other at the end of the furnace. It was held in place by buckstays.
Cooling vault	The space beneath the hearth of the furnace, which is arched over to support the hearth.
Down-take	Where furnaces are not provided with their own chimney a down-take diverts the exhaust from the furnace into the system of flues to the stack.
Fire bar	The iron bars used in the fire-box, supported by saddle bars or iron rails.
Fire bridge	The fire bridge is located between the fire-box and the hearth of the furnace and is used to deflect the heat into the furnace itself.
Firebox	The fire-box was located behind the hearth of the furnace. It was fitted with saddle bars and fire bars for the furnace heat source.
Hearth	The hearth is the floor of the furnace, usually made of sands, smelted into place.
Mouth	The mouth of the furnace was located at the front. It was generally used to skim off slag, but could also be used to extract or ladle the copper matte from the furnace.
Saddle bar	A series of saddle bars or iron bars supported the fire bars or grate in the fire-box of the furnace.
Skimming bar	The skimming bar was located at the front or mouth of the furnace. It was used to limit the extent to which the hearth could be emptied of slag or copper matte
Tap-hole	The tap-hole was usually located on the side of the furnace and was used to pour the copper matte from the furnace.
Tie-rod	A series of tie rods held the buckstays in place, thereby supporting the whole furnace structure.

EXECUTIVE SUMMARY.

The archaeological excavation of the site of Smelter No. 1 was completed prior to mining. It revealed the remains of a smelting hall containing 5 reverberatory furnaces (Furnaces 1 - 5), with two other furnaces in separate buildings. One of these other furnaces was a reverberatory furnace (Furnace 6) and was the best preserved example on the site, with its floor surviving intact. The other furnace (Furnace 7) was a small polyhedral structure of brick and stone, used for calcining and probably a rare conical furnace.

The furnaces and other structures, including a blacksmiths shop and assay office, were constructed by the Scottish Australian Mining Company between 1861 and 1862 and continued in intensive use until 1868 and then sporadically thereafter into the 1880s. The smelting hall was contemporary with the well preserved Cadia Engine House.

The remains of the reverberatory and other furnaces of Smelter No. 1 have an ancestry which goes back to the German origins of the smelting industry in Swansea, South Wales and elsewhere in the United Kingdom in the 16th century. The Welsh brought this technology to Cadia, as did the Cornish bring the deep copper mining technology, after upheavals in the respective copper smelting and mining industries in South Wales and Cornwall.

Copper Smelter No. 1 at Cadia represents the formative stages of the copper mining industry in New South Wales, an industry already introduced in South Australia in 1845. The technology spread rapidly to New South Wales with the construction of a number of smelters, mostly inefficient, at Copper Hill and Summerhill. The Cadia Copper Smelter No. 1 was the first successful copper smelter on a mining site in New South Wales. The archaeological investigation revealed many details of reverberatory and other furnace construction, including the work processes used on site and the adaptation of the smelting process to local conditions.

1. INTRODUCTION.

1.1. Background.

This report was commissioned by Cadia Holdings Pty Limited in July 2001. The archaeological investigation of the site was a condition of the archaeological assessment report, prepared by Edward Higginbotham & Associates Pty Ltd.[1]

The site of Smelter No. 1 is part of the listing for Cadia Copper Mine, including Engine House and Ruins, as gazetted on the LEP for Cabonne Council. Cadia Engine House and Surrounds are also listed on the State Heritage Inventory.[2]

The archaeological remains of historical mining at Cadia were the subject of a conservation plan in 1995, in advance of the existing Cadia Hill Gold Mine.[3]

The archaeological excavation was carried out in accordance with an excavation permit approved by the Heritage Office of NSW on 14 June 2001.

1.2. Brief.

The purpose of this report is to recover the archaeological significance of the site of Smelter No. 1 prior to final development of the Cadia Hill Mine.

1.3. Location of site.

The subject site is located beside the former alignment of Old Cadia Road at Cadia, between the road and Cadiangullong Creek, south of Hoares Creek. (Figure 1.1).

[1] Edward Higginbotham & Associates Pty Ltd. Archaeological assessment of proposed development, site of Smelter No. 1, Old Cadia Road, Cadia, NSW. Cadia Holdings Pty Limited. 2001
[2] Search results of State Heritage Register and Inventory, 27 March 2001.
[3] Godden Mackay, Cadia Mining Project, Final Conservation Plan. Newcrest Mining Limited. 1995. Volumes 1-6.

1.4. Study methodology and limitations.

This report has been prepared in accordance with the Heritage Office and Department of Urban Affairs and Planning guidelines.

The historical background has been summarised from previous reports, but with the addition of new research..

1.5. Author identification.

This report was prepared by Dr. Edward Higginbotham and Kevin Hickson and edited by Edward Higginbotham.

Site survey of the site of Smelter No. 1 was undertaken in June and August 2000, by Edward Higginbotham, Kevin Hickson, Martin Lawler and Tim Adams.

Archaeological excavation was completed by Dr. Edward Higginbotham, Kevin Hickson, Tim Adams and Martin Lawler between 16 July and 17 August 2001.

Site planning of the excavation was completed by Tim Adams, assisted by Kevin Hickson. Computer plans were completed by Kevin Hickson and edited by Edward Higginbotham.

Artifact analysis was completed by Rowan Ward (Ceramics), Jean Smith (Glass), Dominic Steele (Bone) and Kevin Hickson (Metals).

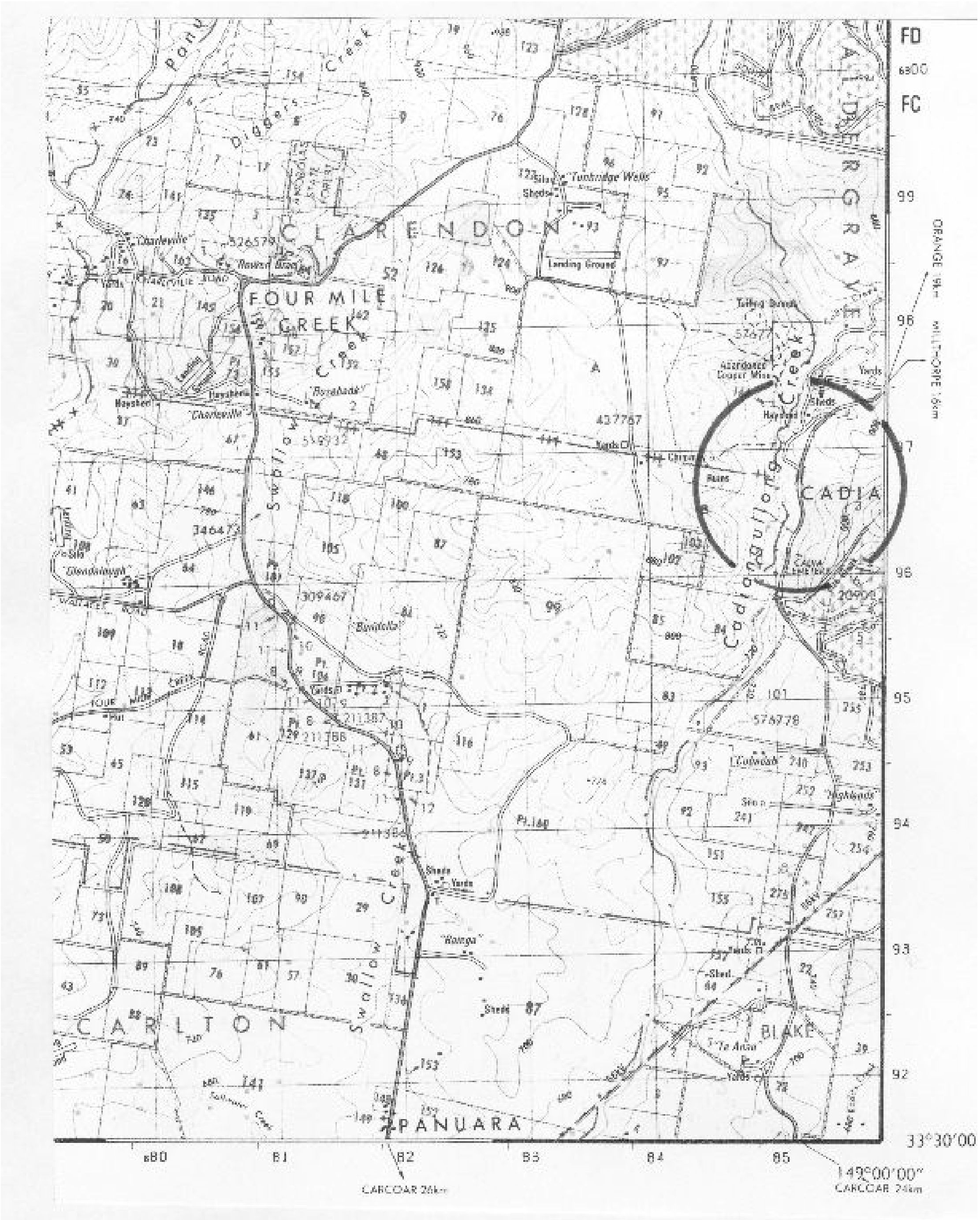

Figure 1.1 Location plan of the historical mine at Cadia, NSW, showing the site of Smelter No. 1.

2. SEQUENCE OF DEVELOPMENT.

2.1. Introduction.

This report provides and overview of the history of mining at Cadia, as well as an overview of copper mining in New South Wales to place the Cadia copper mine in context. Most of the text may be found in previous reports on Cadia, with the exception of detailed references to the Smelter and additional material from Carne.

2.2. The emergence of copper mining in Australia and New South Wales.

Copper mining commenced in South Australia in 1844. The discovery of the rich copper lodes at Kapunda in 1844 and Burra in 1845 opened up a major copper producer, which was to continue in production for many years.[4] The four big sites were Kapunda (1844 - 1879), Burra (1845- 1877), Kadina-Walleroo and Moonta (1862 - 1923). Both Kapunda and Burra were phenomenally rich and easy to work, fetching high prices on the international market, when Cornish mines were the only real competition. Before 1860, South Australia was the third largest producer of copper after the UK and Cuba. At its peak, Kapunda produced 300 to 400 tonnes of dressed ore a year and Burra (the Monster Mine) 16,000 tonnes. The main lode at Burra was worked out by the 1870s.

The production of the Moonta and Walleroo mines from 1860 to 1889 averaged 5,000 tonnes a year and peaked in 1907 at 8,600 tonnes a year. The mines finally closed in 1923.

Cornish influence was strong with trained mine managers in charge of mining works. They built Cornish engine houses and the many small two room cottages to house the miners. Welsh expertise was also used in the construction of the smelters at Kapunda / Burra in 1849. Another smelter was erected at Walleroo in 1861.

The early finds of copper in South Australia alerted potential investors to the possibility of copper in other parts of Australia. However the copper fields of

[4] J E Carne, *Copper Mining* 1908, p. 6-7.

Queensland were not exploited until the 1870s, while those in Tasmania were only opened up in the 1880s.[5]

In NSW, most of the early copper finds were of smaller ore bodies and often of poorer quality ore. In later years, rich copper lodes were found at Cobar and Cangai. The first mines in NSW were opened in 1844 and 1845 at Copper Hill, near Molong, and at Lipscombe Pools Creek, near Canowindra. Another mine was in progress at Summerhill Station, near Rockley, in 1847. As the Bathurst Copper Mining Company it published its prospectus in the *Bathurst Advocate* in 1848.[6] In other words, these mines followed on directly from the discoveries in South Australia and may be regarded as part of the initial development stage of the industry from the 1840s to 1860s.

The first ores mined in South Australia and New Zealand were shipped to England for smelting. The first official record of smelting is at the Newcastle Copper Smelting Works in 1846, using ores from South Australia. The nature of the copper finds ensured that few mines could support a major processing facility. Hence, concentrating furnaces, which produced a semi-finished product, were established at some of the richer finds, where the copper ore could be reduced to copper matte before it was shipped overseas for final processing.[7]

Carne listed the major copper finds in NSW (until 1908), as well as showing which of them possessed reverberatory furnaces.[8]

(* = furnace established).

Date	**Mine**	**Mining District**	**Division**
* 1845	Copper Hill	Lachlan[9]	Molong
1845	Little Copper Hill	Lachlan	Molong
1845	Belubula	Bathurst	Canowindra
* 1846	Summerhill	Bathurst	Rockley
1847	Summerhill	Bathurst	Rockley
1848	Good Hope	Southern	Yass

[5] J. M. Birmingham, “Copper, Tin, Silver, Lead and Zinc” in J M Birmingham, I Jack & D Jeans, *Australian Pioneer Technology*, Heinemann Educational Australia. Richmond, Victoria, 1979: 59-77.
R I Jack, Cadia Village Site. Statement of Significance in a comparative context. Cadia Holdings Pty Limited, 2001.
[6] J E Carne, *Copper Mining* 1908, p. 6-7.
[7] E Carne, *Copper Mining* 1908, p. 7-9.
[8] J E Carne, *Copper Mining* 1908, p. 10-11.
[9] Carne incorrectly gives the Mining District as Bathurst, when Molong is in Lachlan.

* 1849	Good Hope	Southern	Yass
* 1850	Coombing Park	Bathurst	Carcoar
* 1850	Carangera (Cornish Settlement)	Bathurst	Orange
* 1851 to 1865	**Cadia**	Bathurst	Orange
1851 to 1865	**Cadia Extended**	Bathurst	Orange
* 1851 to 1865	Icely	Bathurst	Orange
* 1852	Ophir	Bathurst	Orange
1851 to 1865	Britannia	Bathurst	Orange
1851 to 1865	Belmore	Bathurst	Orange
1851 to 1865	Moonta	Bathurst	Orange
1851 to 1865	Nelson	Bathurst	Orange
1851 to 1865	Geurophian	Bathurst	Orange
* 1872	Essington	Bathurst	Rockley
* 1874	Frogmore	Southern	Frogmore
* 1874	Pride of Frogmore	Southern	Frogmore
1874	Lobbs Hole	Tumut & Adelong	Kiandra
* 1874	Snowball	Tumut & Adelong	Gundagai
* 1874	Belara	Mudgee	Wellington
* 1875	Apsley	Bathurst	Bathurst
* 1875	Belmore	Bathurst	Bathurst
1875	Glamorgan	Clarence & Richmond	Copmanhurst
1875	Bobby Whitlow	Peel & Uralla	Bingara
* 1876	Burraga	Bathurst	Burraga
* 1876	Wertago	Albert	White Cliffs
1877	Burley Jacky	Bathurst	Cowra
1877	Esmerald	Bathurst	Bathurst
* 1877	Bundarra	Peel & Uralla	Bingara
* 1878	Mount Hope	Cobar	Mount Hope
* 1878	Great Central	Cobar	Mount Hope
1878	Cyclops	Tambaroora & Turon	Stuart Town
1878	Mount Ragan	Bathurst	Orange
1878	Green Swamp	Bathurst	Bathurst
* 1879	Nymagee	Cobar	Nymagee
* 1880	Girilambone	Cobar	Nyngan
* 1881	Blayney	Bathurst	Blayney
* 1881	Eurow & Vychan	Lachlan	Forbes
* 1881	Trough Gully	Peel and Uralla	Nundle
* 1881	Lake George (Captain's Flat)	Southern	Bungendore
1888	Pluck	Clarence and Richmond	Copmanhurst
* 1886	Mount Boppy Copper	Cobar	Canbelego
1887	Mount Jasper	Hunter and Macleay	Port Macquarie
1888	Sydney-Wallaroo	Mudgee	Dandaloo
1890	Mount Laut	Mudgee	Denison Town
1891	Willi Willi	Hunter and Macleay	Kempsey
* 1894	Mount Everest	Peel and Uralla	Bingara
* 1895	Gulf Creek	Peel and Uralla	Barraba
* 1895	Mountain Run	Bathurst	Rockley
* 1895	Phoenix	Bathurst	Oberon

1897	Tuglow	Bathurst	Oberon
1897	Christmas Gift	Mudgee	Dandaloo
1898	Elizabeth	Mudgee	Dandaloo
1898	Mount Pleasant	Mudgee	Dandaloo
1898	Bob's Mount	Bathurst	Orange
1898	Monaro	Tumut and Adelong	Cooma
1899	Kangiara	Southern	Yass
* 1899	Sugarloaf	Bathurst	Rockley
* 1900	Crowl Creek	Cobar	Nymagee
1900	Lobb's Hole Central	Tumut and Adelong	Kiandra
* 1901	Cangai	Clarence and Richmond	Copmanhurst
1901	King of England	Lachlan	Cowra
1901	Canbelego	Cobar	Canbelego
* 1902	Queen Bee	Cobar	Cobar
1902	Attunga	Peel and Uralla	Tamworth
* 1903	Mount Royal	Mudgee	Dandaloo
1903	Underlay	Mudgee	Dandaloo
1903	Namoi	Peel and Uralla	Tamworth
1903	A1 Tinby	Tambaroora and Turon	Stuart Town
* 1905	Bogan River	Mudgee	Dandaloo
1905	Cowfell	Lachlan	Cowra
1905	Cash (Essington)	Bathurst	Rockley
1905	Lucky Hit	Southern	Goulburn
1906	Native Bee	Mudgee	Wellington
1906	Orange Plains	Mudgee	Dandaloo
1906	Ace	Mudgee	Dandaloo

(* = furnace established).

The table above, if taken at face value, is quite misleading. One could assume the following:

1. Cadia was between the sixth and the eighth mine in New South Wales to have a smelter.
2. A total of 37 mines possessed smelters between 1845 and 1908.

In fact further research of individual mines in Carne points to another and most important conclusion. The following mines were researched in the order they appear in Carne's list:

The Copper Hill Copper Mine.

The Copper Hill Copper Mine, just north of Molong, was the first opened up in New South Wales in 1845. It is listed as having a smelter by Carne, but the most likely date for its construction is 1847-1851. In

1847 a company was formed to work the lode, with Mr. (later Sir) Samuel Want as managing director. “Shafts were sunk 70 and 146 feet, and smelters erected. A quantity of ore was converted to regulus and carted to Sydney.....” The company ceased operations in 1851, when gold was discovered. A Mr. Clymo was formerly manager of the mine.[10]

Carne further states that “Some unsuccessful attempts at smelting had been made, the failure of which Mr. Scutchbury attributed to probably the unsuitable open-mouthed furnaces adopted.”[11] The fact that S. Scutchbury, the first Government Geological Surveyor, reported on the smelters at Copper Hill means that the smelters must have been in operation or have gone out of use before 1855, when he resigned for reasons of ill health.[12] The more likely date of the smelters is 1847 to 1851, which is when the company were operating the mine.

Three later reverberatory furnaces were erected in 1871 by the Molong Consols Copper-mining Company.[13]

The Summerhill Copper Mine.

The Summerhill Copper Mine (Parish Rockley, County Georgiana) was first worked in 1847. It is listed as having a smelter by Carne, but the most likely date for its construction is 1847-1851.

The Bathurst Copper Mining Company was established in 1848 to mine the copper. There were three shafts, one of which was named Clymo’s, which may indicate the involvement of a Mr. Clymo at this mine too. In April 1851, Mr. S Scutchbury described the attempts at smelting, which were in progress. “The experiment of smelting with green timber is in a fair way of being successfully proved. Although working under the disadvantages of an ill-constructed, half worn-out air furnace, the produce of the first process was encouraging.” The fact that a furnace had been erected at the mine was also reported in the Mining Journal, London, in 1854. A Mr. H Clements, the son of the original owner of the Summerhill Estate, described the smelting

10 J E Carne, *Copper Mining* 1908, p. 138-139.
11 J E Carne, *Copper Mining* 1908, p. 139.
12 J E Carne, *Copper Mining* 1908, p. 9.
13 J E Carne, *Copper Mining* 1908, p. 139.

process as heap roasting and reverberatory smelting, "but judging from the frequent occurrence of prills of metallic copper in the slag, the latter was badly performed."

Another reverberatory furnace was erected in 1902.[14]

The Good Hope Copper Mine.

The Good Hope Copper Mine, near Yass, was owned like Cadia by the Scottish Australian Mining Company. It is listed as having a smelter by Carne, but there is no record of a smelter in the description of the mine.

It was opened as early as 1849, but no smelter is mentioned by Carne, even though an asterisk is placed on his table of mines, indicating that a smelter was present, although not the date it was constructed.[15] Further research may reveal the date of construction of a smelter at this mine.

The Coombing Park Copper Mine.

The Coombing Park Copper Mine, located south of Carcoar, was probably opened up in 1849 by Mr. Reed, former mine captain of the failed Belubula Copper Mine (opened in 1845), for T Icely. It is listed as having a smelter by Carne, but the first smelter was erected at the mine by Messrs. Samuel and Young in 1876.[16]

The Carangara (or Carangera) Copper Mine.

The Carangara (or Carangera) Copper Mine, at Byng (formerly Cornish Settlement), was described by S Scutchbury in April 1851. It is listed as having a smelter by Carne, but the most likely date for its construction is post 1872, the smelter being located at Icely.

The Carangara Copper Mining Company Incorporation Bill was the subject of a report by a Select Committee in August 1854. While Carne states that "Mining and smelting were carried on in this locality for a number of years, but no particulars are obtainable of the output", it is unclear whether he is referring to the 1850s to 1860s or the activities

[14] J E Carne, *Copper Mining* 1908, p. 171-172.
[15] J E Carne, *Copper Mining* 1908, p. 11, 253.
[16] J E Carne, *Copper Mining* 1908, p. 137-138.

undertaken by the Great Western Copper Mining Company from 1872 onwards.

The Carangara Copper Mining Company worked a number of mines, extending to Lewis Ponds, including Britannia, Belmore, Moonta, Nelson, Gurophian, Ophir, Icely, East Block, Mt Fraser, Algar and others. These mines were opened up from the 1850s or later and were floated into a public company in 1872, known as the Great Western Copper Mining Company.[17] According to Captain W R Reynolds, a former company mine manager, the Great Western Copper Mining Company has its smelter at Icely, which smelted the ores from the other mines.[18]

Cadia Copper Mine.

According to the earliest official record available to Carne, dated to 1870, the Cadia Copper Mine had "a complete range of furnaces".[19] Other research presented in this report indicates that the furnaces were built in 1861 and 1862.

The Great Western Copper Mining Company, Icely.

The Great Western Copper Mining Company was formed in 1872. According to Captain W R Reynolds, a former company mine manager, the Great Western Copper Mining Company has its smelter at Icely, which smelted the ores from the other mines.[20]

Ophir Copper Mine.

Although the Ophir Copper Mine was opened up in 1852 and taken over by the Great Western Copper Mining Company, no smelter at this location is described by Carne, even though he had listed a smelter for the mine. Again it is assumed that the smelter, to which the list may refer, is located at Icely under the management of the Great Western Copper Mining Company.[21]

[17] J E Carne, *Copper Mining* 1908, p. 134.
[18] J E Carne, *Copper Mining* 1908, p. 143-144.
[19] J E Carne, *Copper Mining* 1908, p. 127.
[20] J E Carne, *Copper Mining* 1908, p. 143-144.
[21] J E Carne, *Copper Mining* 1908, p. 161.

On the basis of research of each mine as described by Carne, a more accurate picture of the date of the commencement of smelting processes at each mine can be gauged. The results may be tabulated as follows:

Commencement date for mining.	**Mine**	**Date of smelter.**	**Notes**
1845	Copper Hill	1847-1851	"unsuitable open-mouthed furnaces".
1846	Summerhill	1847-1851	"an ill-constructed, half worn-out air furnace".
1849	Good Hope	unknown	No smelter described.
1850	Coombing Park	1876	
1850	Carangera (Cornish Settlement)	unknown	Probably located at Icely.
1851 to 1865	Cadia	1861-1862.	
1851 to 1865	Icely	Post 1872	
1852	Ophir	unknown	Probably located at Icely.

On the basis of this additional research, it is clear that Cadia is the first mine to have a relatively efficient and complete range of copper smelting furnaces in New South Wales. The earlier sites had defective smelting furnaces, as described by Scutchbury or Carne. By making entries for one smelter under the name of two or more mines, the total number of mines listed by Carne must also be an over-estimate of the actual number of mines with smelters.

There is also one other complicating factor, namely that Carne did not list smelters that were at locations independent of mines. In fact, the first official record of smelting in Australia is at the Newcastle Copper Smelting Works in 1846, using ores from South Australia.[22] These smelters appear to be the ones located at Smelters Beach, on Thomas Mitchell's Burwood Estate, just south of Newcastle.[23]

R I Jack, referring to Carne, has made the claim that the smelter at Cadia is the first reverberatory furnace in New South Wales. He also claims that the smelter at the Carangara Mine at Byng is earlier. While he indicates that smelters were erected at Copper Hill in 1871, Icely after 1873, Coombing Park in 1876 and Summerhill in 1902, he has ignored the references to earlier smelting at both Copper Hill and

22 J E Carne, *Copper Mining* 1908, p. 10-11.

23 J. M. Birmingham, "Copper, Tin, Silver, Lead and Zinc" in J M Birmingham, I Jack & D Jeans, *Australian Pioneer Technology*, Heinemann Educational Australia. Richmond, Victoria, 1979: 75.

Summerhill, both in 1847 - 1851.[24] The smelter at Summerhill was described as a reverberatory furnace.[25]

2.3. The development of mining at Cadia.

The earliest discovery of copper traces at Cadia has been attributed to the Geological Surveyor for NSW, Samuel Stutchbury, who located copper traces near Oakey or Cadiangullong Creek on 18 July 1851. This discovery coincided with the discovery of gold in NSW. His report was published in the *Votes and Proceedings of the Legislative Council*, for 1851, thus alerting potential investors to the deposit. At that time, however, the discovery of gold in the same area attracted the bulk of popular interest.

When land near the future Cadia was advertised for sale in the *Sydney Morning Herald* on 2 May 1851, the presence of some copper traces on the land was noted in the advertisement. This land was later purchased as Portion 41, Parish of Waldegrave on 28 July 1859 by William Tom, George Hawke, Richard Lane and Edward Nicholls as trustees for the Canoblas Copper Mining Company.

Portions in the two parishes in which copper traces were found, the Parishes of Waldegrave and Clarendon, County of Bathurst, were taken up by various groups of investors, mainly from pastoral, mercantile or professional backgrounds. Portion 162 of the Parish of Waldegrave, was taken up by J S Rodd, and the two Portions to the north, Numbers 83 and 87, were taken up by Saul Samuel, R J Want and Thomas Icely. Further east, Portion 41 of Waldegrave was taken over by the Trustees of the Canoblas Copper Mining Company. Portions 147, 148 and 149 of the Parish of Clarendon, where the Cadiangullong Copper Company operated from the 1860s and where the Cornish Engine House was later built, were taken up by William Lawson, Thomas Icely, William Jones and J S Rodd. These Portions were originally advertised for sale on 22 May 1855 and were bought by J S Rodd on behalf of the four partners.

There were three areas of mining at Cadia, East Cadia, Little Cadia and West Cadia. The earliest mining operations appear to have been at East Cadia, which was situated on the eastern side of the creek in the Parish of Waldegrave. Portions 83, 86, 87 and 27, 29 and 30 of the Parish of Waldegrave, were taken up by a consortium consisting

[24] R I Jack, Cadia Village Site. Statement of Significance in a comparative context. Cadia Holdings Pty Limited, 2001. See text under headings for Criteria C, E and F.
[25] J E Carne, *Copper Mining* 1908, p. 171-172.

of William Lawson, Thomas Icely, William Jones and J S Rodd (Directors of the Cadiangullong Consolidated Copper Company).

The second of the mining areas was known as Little Cadia. The Canoblas Mine (later known as the Cadia Extended Copper Mine) was located on Portions 28, 37 and 38 of the Parish of Waldegrave. Portions 37 and 38 had been purchased by Saul Samuel and J S Rodd on 16 July 1856, whilst Portion 28 had been purchased on 19 May 1859. It is believed to have been on these portions that Stutchbury found evidence of copper in July 1851. This operation, named the Canoblas Copper Mine at Little Cadia, continued until June 1860 (or 1861), when the lease expired. The owners of the land then sold their interest to the Cadiangullong Consolidated Copper Company (Directors Thomas Icely, William Frederick Jones, John Savory Rodd, Saul Samuel and Randolph John Want). Ore had been carried out of the area for export, but the mine at Little Cadia was soon overshadowed by the much larger Cadia (or Cadiangullong) Copper Mine. Mining at Little Cadia had ceased by the time the North and South Section Mines were in operation at West Cadia, the latter being the third area of mining activity.

At East Cadia, mining concentrated upon Portions 83 and 87 of the Parish of Waldegrave.[26] On 15 July 1861, John Savery Rodd, Saul Samuel, Randolph John Want, and Thomas Icely (Cadiangullong Consolidated Copper Company) leased to Robert Archibald Alison Morehead & Matthew Young, Sydney, esquires, who were the Australian representatives of the Scottish-Australian Mining Company, the three portions numbered 87, 83 and 162 in the Parish of Waldegrave for 21 years from 1 July 1861 for copper mining purposes. The royalty was to be one-twelfth of all copper ore raised, dressed and ready for the furnace, or alternately one twelfth of this once refined. Work on mining was to commence before October 1861 and was to be undertaken continuously with a minimum of 6 able bodied miners. If the mines had to stop due to a "Strike of Workmen or such rise of Wages as shall in the opinion of the lessees... render it desirable temporarily to suspend the working of the mines on the said land in order to import labour", the lessees were to pay a weekly rent of £25. The land let consisted of Portions 87, 83 and 162, excepting a part in the north-west corner of Portion 87 measuring 23 chains along the north boundary of the grant, 20 chains on the east and then a line back to Cadiangullong Creek and then northwards along creek.[27] In December 1861, the *Western Examiner* newspaper of Orange noted that

[26] Plan of the Cadia Properties 1881
[27] RPA 2120 in SRNSW 10/26437

there was a large quantity of ore at "this extensive mine" and that a smelter was being erected.[28]

The Scottish-Australian Mining Company commenced their Oakey Creek Copper Mine at East Cadia, which was later renamed the Cadia or Cadiangullong Copper Mine in 1863.[29] Captain Josiah Holman was reported to have arrived to take over the operation of this mine in March 1862. On 13 May 1864, the Cadiangullong Consolidated Copper Company (Directors Thomas Icely, William Frederick Jones, John Savory Rodd, Saul Samuel and Randolph John Want) sold the mine and their land to Morehead and Young, as the Australian representatives of the Scottish-Australian Mining Company.

By 1868, the East Cadia Mine was driven down as far as 23 fathoms according to Joshua Holman, the mining captain, until waterlogging of the workings prevented any further ore being removed. Up to that time it was claimed that 1,300 tons of copper ore had been extracted from that mine.[30]

The third area of mining was located on the opposite or western side of Cadiangullong Creek in the Parish of Clarendon. Portions 147, 148 and 149 were purchased by William Lawson, Thomas Icely, William Jones and John Savery Rodd in April 1852, but sold to the Scottish-Australian Mining Company in May 1864, along with all their other holdings. It is likely that this area was mined or at least prospected before June 1861, since Robert Morehead described an adit being present by that time and also possessed a description of the mine which had been given him in 1858 by a Captain Dalley.[31] So far as is known this is the only justification for Margaret Morris' assertion that mining had taken place before 1861 at this location.[32]

The West Cadia mines were divided into the North and South Sections. The North Section was sited upon Portion 148 of the Parish of Clarendon and the South Section was on Portion 149. In his 1868 report to the Manager of the Company, Holman described the North Section as having a 12 HP portable engine, which was on Trevena's engine shaft, which was 40 fathoms deep with an adit 19 fathoms deep.. At 12 fathoms below the adit, Trevena's shaft was extended west of the shaft on Northey's lode. As well as Trevena's shaft, there were shafts named after Rodd, Hall,

28 *Western Examiner*, 14 Dec 1861
29 B A French, 'Cadia', April 2000, p. 46
30 C Pratten, 'A History of the Cadia Mines', typescript, p. 4.
31 B. A. French. 'A chronology of records of Cadia, 1828 - 1999', 2000, unpaginated. Report, 20 June 1861.
32 C Pratten, 'A History of the Cadia Mines', typescript, p. 4.

Gundry, Samuel, John as well as Icely's. On the South Section was erected the Cornish condensing engine with a 25 inch cylinder and a ten ton boiler, with pumping, winding, stone-breaking, crusher and jigging machinery. This is the extant Cornish engine house.

The Scottish-Australian Mining Company erected the Cornish beam engine and engine house in 1865.[33] Nearby were a smithy with two forges, as large carpenter's shop and engine-fitting shop, with a large lathe, powder magazines and mining office. Phillips' engine shaft was also in this section and went down 32 fathoms. It was connected to Lawson and Want's shafts.

In 1866, after large parts of the land surrounding the mine were closed to miners and woodcutters by a pastoral lease, Holman arranged for the preparation of a petition calling for the declaration of a Common around the mine, so that fuel could be gathered for the mine. This successfully created a Common, which operated for some years until revocation, where fuel for the mines could be gathered. Woodcutters were able to obtain their livelihood and the mines continued to operate.

Excavation of mine shafts at Cadia appears to have been based upon Cornish mine techniques with manual labour being used to work the mines. Miners concentrated on the richest lodes. At some stage by 1868, explosives were being used as Holman noted the existence of a powder magazine.

Despite the investment in mines and plant, equipment and a smelter at Cadia, the Scottish-Australian Company was losing money by 1868, when the price of copper on overseas markets fell. For the rest of the nineteenth century, the Cadia mine opened and closed with the rise and fall in copper prices. Holman reported various attempts to locate payable gold on the company's land. When production was slow, workers left the district seeking employment elsewhere. Sometimes, it was at other mines owned by the company, such as Icely.

The early smelters appear to have been built on the reverberatory principle, which could utilise timber as fuel and was simpler to build and operate. In the furnace, finely ground ore well mixed with the flux was heated for up to 24 hours until the copper matte could be extracted. This was then further refined in a more sophisticated reverberatory furnace. The technology had been developed in Wales and was widely

[33] The *Sydney Mail* of 16 September 1865 describes the engine in the course of erection. Baillier’s New South Wales Gazetteer, 1866, records the engine as complete.

applied in copper mines across Australia. Thus, at Cadia, as in many copper mining settlements, there was an ethnic divide amongst the workforce. Many of the miners were Cornishmen, whilst the smelter staff were often Welsh.

Low copper prices as well as a decline in ore quality caused the cessation of production in 1868. In mid 1868, the mortgagee ordered the sale of the Cadiangullong Copper Mines, but there were no bids and the property remained in the hands of the company. Research by Brian French suggests that the years 1863-67 were a peak period of copper mining activity.[34]

In May 1870, the *Australian Town and Country Journal* reported on the Cadiangullong Mine. By this time, the journalist noted that there were 13 shafts and that almost a mile of tunnel had been dug out in various directions through the ore body. The reporter described the ore smelting process. The smelters were then reducing some ore for the Woods Flat Mine, some 32 miles to the south-west. Boys were employed to pick over the rock and separate the ore from the rock. The best ore went straight to the furnace, whilst the lesser grades were crushed and jigged. This stone was first broken by Appleton's stone breaker into smaller pieces. It was then reduced to smaller size between Cornish cast-iron rollers. Once crushed sufficiently fine, it passed through the eight jigging machines in eight slabbed pits which separated the components by gravity with the ore sands being skimmed off by boys.

Between 1872 and 1877 copper mining was again active at Cadia.[35] About 1877, there was again a spurt in production. The school records show that bricks and timber were being gathered for a new works for the Cadia Mining Company. Carne noted in the 1899 edition of his book on copper mining that a substantial stone engine and pumping house was erected at this time. Carne also noted that about 48 tons of ore was obtained in 1882 and some tributing was done in 1883, but it is not known from which mine this ore was obtained. However, from 1880 onwards, Holman occupied the mine as yearly tenant of the company and continued to work it under a royalty arrangement with the company. As well as smelting some ore, his men sought gold in the vicinity.[36]

French noted that from 1887 until 1890, there was another burst of mining activity at Cadia.[37] In the late 1880s and during the 1890s, copper mining revived at Cadia and

[34] B A French, 'Cadia', April 2000, p. 27
[35] B A French, 'Cadia', April 2000, p. 27
[36] B A French, 'Cadia', April 2000, p. 48
[37] B A French, 'Cadia', April 2000, p. 27

Carne reported that about 2,500 tons of ore of 16% copper was dug out under Holman's direction. Between 1887 and 1899, Carne also claimed that a total of 4,000 to 5,000 tons had been dug from the eastern side of the creek opposite the Iron Duke tunnel and been treated at the Cadia smelters. However, in the Mining Department's Annual Report, he was sceptical of the accuracy of this figure. The Annual Report of the Mines Department of 1889 noted that new machinery worth £1,750 had been installed by the Scottish-Australian Company at Cadia and that £8,000 had been spent on buildings. This expenditure was probably used to build Smelter No. 2, located beside Cadiangullong Creek on the north western side of the Village. A total of 50 tons of ore was dug that year. In 1890, total copper ore raised at Cadia totalled 300 tons, but by 1891, it was believed that copper production had ceased at Cadia.

In the 1890s, copper mining revived, so that Carne was able to report in his 1908 edition of several new shafts, which had been opened at Cadia. When he visited the site in February 1908, he reported that the Iron Duke lode on the western side of the creek in Portions 83, 86, 87 was open and was being "extensively" worked. On the eastern side, the East Cadia Section was being worked along with Chilcott's Shaft. A fourth furnace had been brought into operation.

By 1908, a new 60 ton blast furnace was being built at Cadia for the Cadia Extended Mining and Smelting Company, which was operating on the site of the 1859 Canoblas Copper Mine (Little Cadia). The company does not appear to have had much success.

A new venture to mine at Cadia was under way by 1904. The Cadia Gold Syndicate had been formed to work the area for gold. By late 1904, the Scottish-Australian Mining Company was again working small copper deposits. By 1905, the Cadia Copper Mining and Smelting Syndicate had taken a lease on the Cadia mine from the Scottish-Australian Company and was working it by June 1905 with 8 men, and had 86 in employment by the year's end. A furnace was to be built. By the time of Carne's visit in 1908, there were four reverberatory furnaces in operation. He reported that 200 men were employed at the copper mines, including miners, smelter staff plus wood cutters and carters.

Copper mining soon declined again. By late 1908, the Scottish-Australian Company had given up the lease and, according to the Mines Annual Reports there was no further copper mining until 1913. However, French has identified the period 1909 until 1916 as another peak of copper mining.[38]

[38] B A French, 'Cadia', April 2000, p. 27

Some gold was also being won locally. The Cadia Hill Gold Mining Company was reported to be working a very large low grade deposit south-east of Cadia in 1908. Isolated nuggets were also found in the locality.

A new blast furnace was erected in 1912 after some years of depressed mining activity. In 1913, there were 250 men at work in Cadia and over 19,000 tons of ore was treated. Gold and silver were also obtained from this ore as well as copper. Work continued spasmodically for the next few years. In 1916 a peak of 25,000 tons of ore was treated. Copper mining operations closed down in 1917.

The presence of a large body of iron ore at the Iron Duke on Portions 147 Parish of Clarendon and Portions 83 and 87 of the Parish of Waldegrave had been widely known since 1901 at least when Jaquet described them as the most extensive deposit in the state. William Sandford Ltd, the builders of the steelworks at Lithgow had taken a lease from the Cadia Copper Mining Company to mine the ore on the Iron Duke lode, but had not used it. G & C Hoskins, who took over the Sandford Works, made arrangements to mine the Cadia iron ore. A lease for £1,000 per annum with a royalty of 6 d per ton was signed with the Cadia Copper Mining Company. Work on a rail line from Spring Hill to Cadia commenced.

From 1918 onwards, G & C Hoskins Ltd, the Lithgow iron working company, mined iron ore from the Iron Duke deposit and shipped it out via aerial tramway and railway to their works at Lithgow. By 1919, there were 130 men employed on the mine. On 10 March 1921, an accident with explosives killed nine men in the Iron Duke Mine.

When the Lithgow furnaces of G & C Hoskins closed down in 1927, the company shifted its smelting operations to Port Kembla. Production of iron ore from the Iron Duke fell. A total of 180,108 tons of ore, mostly from Cadia, was used at Lithgow in 1927. But, in 1928, only 84,206 tons was mined at Cadia and a mere 874 tons in 1929. The mines closed.

During the 1930s, there were schemes to recover gold from the Cadia district, most of which did not come to fruition. However, A T Mylecharane was able to successfully win gold from the Iron Duke in the late 1930s. This operation was bought by Cadia Gold Mine Pty Ltd, which installed a stamp battery, bins, amalgamating tables and classifiers.

The Cadia iron ore mines re-opened during World War II to make up the shortfall in shipments of South Australian ore for Port Kembla. From about 1941 until August 1945, ore from Cadia fed the furnaces at Port Kembla. Australian Iron and Steel Ltd refurbished the old railway line from Spring Hill and began to excavate ore from the Iron Duke from August 1941 onwards. A new incline was built to replace the aerial ropeway, which was no longer functioning. The quarrying of the ore continued until 29 August 1945, after which the rails were removed.

During the 1930s and the 1940s, a Mr Tinnock dug small quantities of gold or copper ore. In 1952, the plant of the Cadia Gold Mines Ltd was dismantled and removed.

2.4. Mining and smelting of copper at Cadia.

The early mines at Cadia (Little Cadia, East Cadia, West Cadia, both North and South Sections) were worked on Cornish principles, using hammer and gad to sink shafts into the most productive ores. Blasting with gunpowder was used at an early stage, as indicated by the references to powder magazines.

Ore was processed near to the shafts, as indicated by the presence of tailings and slimes (North and South Section Mines). The ore was first sorted by "picky" boys, with the waste discarded on mullock heaps. Fine ores were sent straight to the smelter, while the remainder was spread on cobbled processing floors, splashed with water to bring out the colour and then again sorted into ore and mullock. The ore was then crushed or milled, followed by jigging (buddles or jigs).

The ore, once finely ground, was transported to the smelter. Smelter No. 1 was constructed between 1861 and 1866.

Smelting is the process whereby copper is separated from the ore in which it is found. The ore is heated in a furnace together with flux to a sufficient temperature to melt the copper. The molten copper is heavier than the ore or flux and sinks to the bottom, where it can be periodically drawn off. Two types of furnace were used at Cadia, the reverberatory or blast furnace. The reverberatory furnace (Smelters No. 1 and No. 2) was the simplest to construct and operate, but had to be carefully supervised. Timber could be used as a fuel, providing the ore was finely ground. The reverberatory furnace possessed a firebox, a stone hearth with a brick dome over it. The furnace was charged with a well mixed supply of ore and flux. It was then fired up for a period of approximately 24 hours, before the matte (copper) and slag were drawn off at different levels of the furnace. The furnace was then cleaned out, any repairs undertaken and a new charge placed in the furnace before recommencement of the smelting cycle.

Smelter No. 1 was located near to a plentiful water supply in Cadiangullong Creek. It is located to the south of Hoares Creek and is the most southerly of the three smelters on Cadiangullong Creek, so as to be located intermediate between the four early mines, particularly Little Cadia and the other mines.[39] Later phases of mining and smelting are not discussed in further detail, since they post date the use of Smelters No. 1 and No. 2.

Copper Smelter	**Date Range**		**Comments.**
Smelter No. 1	1861 to 1864		Reverberatory Furnace. East side of Cadiangullong Creek, south of Hoares Creek
Smelter No. 2	1889	1908.[40]	Reverberatory Furnace. East side of Cadiangullong Creek, at northern end of Village Site.
Smelter No. 3	1912	1915.[41]	Water Jacket Furnace. West Side of Cadiangullong Creek, south of Iron Duke.

[39] Godden Mackay, Cadia Mining Project, Final Conservation Plan. Newcrest Mining Limited. 1995. Volume 1. p. 57-60.
[40] Godden Mackay, Cadia Mining Project, Final Conservation Plan. Newcrest Mining Limited. 1995. Volume 1. p. 61, Volume 5, p. 10.
[41] Godden Mackay, Cadia Mining Project, Final Conservation Plan. Newcrest Mining Limited. 1995. Volume 1. p. 61.

Smelter No. 4	c1908.[42]		Portable Water Jacket Smelter. Located at Little Cadia. There is very little trace of slag on this site, indicating that the smelter was either not used, or was used only for a very short period.

Table 2.1. The copper smelters at Cadia.

2.5. Commercial copper ores.

Copper appears in nature in a number of combinations with other elements, but those of commercial importance are few in number. The following text is summarised from Carne.[43]

Native copper, or pure copper (Cu), was once common in NSW wherever copper ores were located, but occurred only in small quantities. Native copper was present at Cadia (probably Little Cadia).

Cuprite (Red oxide of copper) (Cu_2O) is the richest ore of copper, frequently forming the decomposed and oxidised cones of native copper. Although present at most copper mines in NSW, it has frequently been worked out.

Melaconite (Black oxide of copper) (CuO), although a common occurrence, has rarely been found in NSW, but is often mistaken for a partially altered and enriched sulphide ore.

Malachite (Green carbonate of copper) ($CuCO_3$ + $Cu(OH_2)$ is one of the most frequent ores, along with Azurite in the oxidisation zone, and forms the bulk of direct smelted ores.

[42] Godden Mackay, Cadia Mining Project, Final Conservation Plan. Newcrest Mining Limited. 1995. Volume 6. Inventory Sheet LC09.
[43] J E Carne, *Copper Mining* 1908, p. 17-18.

Azurite (Blue carbonate of copper) ($2CuCO_3$ + $Cu(OH_2)$) occurs frequently in association with Malachite in the upper levels of mines (oxidisation zone), but in less quantities. It may also be direct smelted.

Chalcocite (Copper glance or grey sulphide of copper) (Cu_2S), frequently known as “grey ore” among local miners, is one of the most important copper ores and is usually the result of leaching and redeposition of copper salts from upper levels. It is found in the lower levels of mines.

Bornite or Erubescite (Variegated copper ore) ($3Cu_2S$, Fe_2S_3) is infrequently found, but probably formed from the leeching and redeposition of copper ores from higher levels. It is found in the lower levels of mines.

Chalcopyrites (yellow sulphide of copper) (Cu_2S, Fe_2S_3) is the most widely distributed ore of copper and the most persistent at depth, hence its importance. It is commonly associated with iron sulphide (pyrites), with traces of gold and silver.

Smelting of sulphide ores requires prior roasting or calcining to reduce the amount of sulphur. Alternatively oxide and sulphide ores can be mixed to provide fluxes..

2.6. Ores mined and smelted (Smelter No. 1) at Cadia.

Some of the richest copper ores were mined at Little Cadia in October 1858. On 20 August 1859, it was described in the *Sydney Morning Herald* as ‘composed almost wholly or red and black oxide, native copper, and iron and copper pyrites, and, without exaggeration is one of the most magnificent deposits of copper ores ever found in any age or country.’ These ores may be recognised as native copper (Cu), Cuprite (Red oxide of copper) (Cu_2O), Melaconite (Black oxide of copper) (CuO), and Chalcopyrites (yellow sulphide of copper) (Cu_2S, Fe_2S_3).

By June 1861, Mr. Robert Morehead had visited a number of mines near Bathurst and had inspected workings at Cadia, which may be those at West Cadia, because of the extensive iron outcrop described. He described the ores as predominantly carbonates and oxides and grey ores. These may be recognised as Cuprite (Red oxide of copper) (Cu_2O), possibly Melaconite (Black oxide of copper) (CuO), Malachite (Green carbonate of copper) ($CuCO_3$ + $Cu(OH_2)$, possibly Azurite (Blue carbonate of copper) ($2CuCO_3$ + $Cu(OH_2)$ and certainly Chalcocite (Copper glance or grey sulphide of copper) (Cu_2S).

The Company commenced mining at West Cadia in July 1861. By November of that year they had mined about 600 tons of ore, including a small quantity bought from the previous mining enterprise. In the month ending 15 November 1861, it was reported that 200 tons of ore was raised, which could yield as much as 40% copper, and that the entire amount of ore so far raised could yield 20%. The ore was described as native copper among other oxide ores. It was reported to the AGM in February 1862 that Captain Christoe was attempting at that time to prospect the whole of the mineral resource at the mine.

The *Sydney Mail* of 16 September 1865 described the ores being obtained from the North and South Section Mines as 'yellow sulphurets', in other words Chalcopyrites (Cu_2S, Fe_2S_3). The same report also indicated that the sulphide ore is mixed with the higher grade ores for smelting purposes, since the iron and silica in the sulphide ores act as a flux. The article also describes 'carbonate of oxide ores' being smelted at Cadia. This is more likely to be Malachite ($CuCO_3$ + $Cu(OH_2)$ rather than Azurite ($2CuCO_3$ + $Cu(OH_2)$.

The report by Captain Josiah Holman of 11 June 1868 indicated the presence of native copper thinly dispersed through the iron stone at East Cadia, while the iron pyrites contained nearly payable quantities of gold for working. Also at this mine, red oxide of copper (Cuprite (Cu_2O)) formed a superficial covering of the ore, thickly studded with native copper, though this rich ore was surrounded by less valuable ores (probably sulphide ores, since there is reference to iron and gold content). By 1868 a total of 1341 tons 8 hundred weight of ore had been raised and estimated to yield 123 tons 16 hundred weight 1 quarter 2 pounds of fine copper, averaging 9.23 per cent.

At North Section, extension of the mine had been made, while 3,000 tons of unspecified copper ore had been previously extracted.

At Phillip's Engine Shaft rich ores were encountered from the surface to the deepest levels. At 26 fathom depth a 4 ton sample of fine yellow sulphurets of copper (Chalcopyrites (Cu_2S, Fe_2S_3)) were mined. Large quantities of ore (probably sulphide) were obtained from this and neighbouring shafts on the South Section. In all about 2,000 tons of ore had been mined at South Section. The total of West Cadia (North and South Section) production was 5164 tons 12 hundred weight 1 quarter, yielding by assay 649 tons 15 pounds of fine copper, an average of 12.566 per cent.[44]

2.7. Detailed references to the first phase of copper smelting at Cadia (Smelter No. 1).

The Director's Reports of the Scottish and Australian Mining Company from 1859 to 1909 and other historical documents provide valuable information on mining and smelting at Cadia.[45]

The Scottish Australian Mining Company was formed in December 1859. It had engaged Captain John P Christoe by May 1860 to prospect mining opportunities in the Bathurst District. The Company leased land for the mine at Cadia by July 1861 and had purchased 25 acres for the erection of a smelter at a price of £2 an acre.

Mr. John P Christoe, described as a metallurgist, was an invaluable asset to the company. In a letter from Mr. Robert A. A. Morehead, dated 20 July 1861, it is stated that Mr. Christoe 'can proceed to erect furnaces, and to carry on smelting with the confidence that is engendered by his having already done all this, with perfect success, in the neighbourhood; his local expertise, therefore, will enable him to proceed with an economy and efficiency that no other metallurgist could bring to bear.'

Mr. Morehead nonetheless would proceed with caution, in order to satisfy the Directors of the Company and justify his approach. He stated that "I am, however, pretty confident that what we now contemplate will not involve an outlay of £2,000; and when I speak of the works we now contemplate, I should explain that this refers to the construction of several furnaces, and that, of course, one will be completed first

44 B. A. French, 'Extracts from the Directors Reports of the Scottish Australian Mining Company, 1868-1909', September 2000. unpaginated.
45 B. A. French, 'Extracts from the Directors Reports of the Scottish Australian Mining Company, 1868-1909', September 2000. unpaginated.

and the others proceeded with only if the (confidently) expected inducement from mining operations offers itself."

Mr. Morehead also described his decision to erect the engine and crusher at Cadia in this same letter. It had been imported in May 1860 for the Good Hope Mine, owned and developed by the Company, near Yass, but had been left in storage in Sydney until required.

On 27 July 1861, Captain Christoe reported that he had found 'on the Property a clay for making fire bricks, quartz in abundance, and a quarry of superior rubble stone,' all of which would assist in the construction of the smelter.

By 31 December 1861, the following inventory of expenses indicated the extensive nature of work at the Cadiangullong Mine, including the erection of Smelter No. 1. The total cost of the smelter was estimated at £2,000 and was nearly completed for the AGM held on 7 February 1862.

31 December 1861 - Cadiangullong Stock Plant, Improvements, etc. in the Cadiangullong Mine and Works.[46]

Smelting shed	120 x 60 ft	Bark roof	£95		
Refiner's House	30 x 15 ft		£21		
Double House	40 x 12 ft		£22		
2 Single Houses	20 x 12 ft		£22		
1 Single house	22 x 12 ft		£16	10s	
Assay Office (Weigh House, furnace, etc)	42 x 15 ft	Shingled	£53		
Stack and culvert			£402	3s	4d
Ore flow culvert			£38	18s	4d
Wood, 1034 tons cut and carted @ 4/1 [per ton]		[47]	£211	2s	2d
Ditto 309 tons @ 2/3d [per ton]			£34	15s	3d

[46] B. A. French, 'Extracts from the Directors Reports of the Scottish Australian Mining Company, 1868-1909', September 2000. unpaginated.
[47] This total was listed as £402. 3s. 4d and is incorrect for the rate given. It may be a transliteration from the sum for the stack and culvert above.

Lime 140 bushels burned and carted @ 2/2d [per bushel]		[48]	£15	3s	4d
Ditto 371 @ 2/1d		[49]	£38	12s	11d
Fire bricks 19,000 @ £6. 10s. [per thousand]			£123	10s	
Common bricks 25,000 @ 27/6d [per thousand]			£34	7s	6d
Quartz 17 tons @ 15/- [per ton]			£12	15s	
Plant					
1 fire brick machine			£20		
Brick maker - 8 narrow barrows @ 40/-		[50]	£16		
3 iron Nibbles			£1	4s	
2 adzes				12s	
2 spades				13s	
2 Powder cans				4s	6d
6 gimlets				2s	
	[total]		£1	11s	6d
1 can				3s	
2 brushes				2s	1d
Chisel				1s	9d
Hacksaw				7s	
	[total]			13s	10d

[48] This total was listed as £15. 7s. 4d and is incorrect.
[49] The total number of bushels was listed as 381 and is incorrect.
[50] The total number of barrows is listed as 6, but this would give a total of £12, not £16. Either the number of barrows or the sum of £16 is incorrect. In the table the number of barrows is corrected.

Mine Buildings.					
Powder Magazine			£16		
Captain's House and working office	60 x 15 ft		£52		
Closet, etc			£2		
Blacksmith's and Carpenter's shop	42 x 15 ft		£23		
Carpenter's and Engineer's House			£27		
Store and Back Shed for hay			£8		
Manager's House			£80		
Well			£8		
Dam, Race, etc for ore floors			£48		
Outlay on weir of dam @ £15		[51]	£63		
Grass Paddock of 330 rods			£66	3	
Cultivated Paddock			£48	18	4
Stock Yard			£8	0	6
2 Bridges, cutting of road, works and quarry			£72		
Total		[52]	£483	1	10

The wandering reporter for the *Sydney Mail* described the Cadiangullong Mines, including the smelting works on 16 September 1865. Mr. Holman was identified as the Mine Captain, while Mr. Christoe, the company's assayer, was in charge of the smelting works.

> "These works are situated on the eastern side of the creek, and at the southern end of the settlement. These consist of six furnaces at present at work, one in course of building, and an eighth shortly to be commenced. They are what are known as draught furnaces, the draught

[51] This figure appears to be incorrect.
[52] The actual total for the figure given is £522. 1s. 10d. This means that there are some mistakes in the addition, or the figures have not been accurately transposed from the original or they were illegible.

> being furnished by the flues of the furnace being connected with a tunnel about sixty yards long, ending in a tall stack of chimney. When the whole of the six furnaces are at work, the draught that this long flue causes, is very much greater than would generally be believed. In fact, so much so, that recently in clearing out the tunnel, the residuum of sulphur, &c., that hung upon the walls, gave in smelting a very large per-centage of copper, showing that even by this modification some of the metal was volatised and carried off in vapour."

Earlier in the same article, the reporter had noted the consequences of this process for the community:

> "The snort of the steam, the clang of the engine, and the roar of the furnace mingle with the hum of human voices, and give a stranger impression than that conveyed by a newly opened gold field, for above all and pervading all there is an unmistakable sulphur odour, somewhat irritating at first to persons of delicately sensitive olfactory nerves."

The wandering reporter continues to describe the smelting process in detail:

> "The first process to which the ore is submitted is that of calcining, by which the water and some of the earthy particles are removed. The second is smelting the calcined ores, by which a large portion of the siliceous matter is taken out, the remainder forming with the iron into a slag that has been found to be a valuable flux for the richer ores. The third process is the melting of the results of No. 2, which gives a regulus of about 45 per cent., with the best carbonate of oxide ores, containing themselves a per-centage of from 20 to 30 of copper. This brings on the metal to about 60 to 65 per cent., and it then undergoes the fourth process by being charged into the wasting furnace, by which it is brought up to about 80 per cent. By the fifth process it is returned in blocks to the roasting furnace, where it is roasted into copper of about 98 per cent. The sixth and last process is charging the process of No. 5 into the roasting furnace, where it is converted into pure copper of standard quality. In this last instance, the charge is usually about 8 tons, and the process occupiers twenty-four hours. In the calcining furnace about 40 to 60- tons a week are roasted and prepared for the subsequent operations, the quantity of course decreasing as the various operations are gone through. The quantity of ore smelted is usually

> about 200 tons per month, and this gives a monthly yield of about thirty tons of pure copper, being at the rate of from 15 to 16 per cent. The smelting is all done with wood for fuel, and for the above quantity of ore no less than 1200 tons of firewood are consumed."

The next detailed description of the Cadiangullong Copper Mines is contained within a report by Captain Josiah Holman, who had been engaged by the Company in March 1862. The report is dated 11 June 1868.

> "SMELTING WORKS.--The large shed covered with galvanised iron is 125 by 60 feet, under which are three copper ore furnaces, one roasting furnace and a refinery furnace. One ore smelting furnace and the refinery are complete, the others having had their bottoms recently taken out, will require rebuilding above the foundations. The ironwork of these is complete, and the whole of these furnaces could quickly be put in efficient working order. A detached galvanised iron covered shed 60 by 50 feet, contains one new copper ore smelting furnace complete, by having a new bottom. A detached galvanised iron shed, 35 by 25 feet, covers a calcining furnace. Detached is a smith's shop with forge, anvil, vice and tools; also sets of smelting tools for immediate resumption of works. An assay office built of slags, with shingled roof 29 by 18 feet, contains two furnaces, assay tools, scales, weights, crucibles, chemicals and fluxes for assaying, with office furniture, stationery, &c, &c. One of Avery's large weighing machines and a weighbridge used for weighing the fuel for the works.
>
> The quantity of copper ores smelted at the works has been 7695 tons 12 hundred weight and 3 quarters, yielding a gross produce in refined copper of 837 tons 11 hundred weight and 6 pounds, viz: from East Cadia Mine 1341 tons 8 hundred weight; West Cadia 5164 tons 7 hundred weight i quarter, together estimated to yield 772 tons 16 hundred weight 1 quarter 17 pounds of copper and purchased ores from Canoblas Mine 871 tons 16 hundred weight 1 quarter; Carangara Mines 318 tons 5 hundred weight 1 quarter; and having produced as above stated 837 tons 11 hundred weight 6 pounds of refined copper. These works are capable of reducing over 300 tons of copper ore monthly"

The advertisement in the *Sydney Morning Herald* for 16 May 1868 for the mortgagee sale of the mine, which had by that time closed down, included a further but brief description of the smelting works:

> "1 Manager's house, and a large number of miners' houses, assay office, 2 blacksmith shops, 3 smelting furnaces, 1 roaster and 1 calcining furnace, 1 large shed with iron covered roof, 3 ditto covering furnaces."

2.8. Investment and mining strategy for historical copper mines.

Carne lamented that many mines in the 19th century were worked on an ad hoc basis, without any system or planning ahead. He indicated that many mines failed because they did not plan ahead by prospecting the available mineral resource or by chemical analysis of the sulphide ores which would be reached at lower levels.[53]

On the other hand, mines which adopted a system or planned approach to mining would have no reason to fail. A planned approach to mining included:

1. Exploration of the resource ahead of stopes, using shafts and winzes. These mines were able to keep in sight a considerable reserve of ore.
2. Mining at all levels of the mine, so that oxide and sulphide ores were available for judicious mixing in the smelting furnace, without over use of fluxes.
3. Analysis of both oxide and sulphide ores to determine best smelting results and mixes of ores. Early analysis would allow a mine to develop the most appropriate smelting works, so that additional capital and development were not necessary at a later stage.

Capital investment could more easily be obtained for the mining and smelting of shallower oxide ores, because it paid good dividends. Investment was more difficult to obtain for the mining and smelting of deeper sulphide ores, because the returns on investment were lower or longer term. Many mines failed once they reached the sulphide ores because of the extra capital required. Carne advocated that provision should have been made for this capital investment in the early stages of oxide mining, so that there were steady returns or dividends for both oxide and sulphide ore

[53] J E Carne, *Copper Mining* 1908, p. 14-15.

extraction, rather that a sudden demand for more capital and hence failure of the mine on reaching the sulphide ores.[54]

Captain Josiah Holman reported on 11 June 1868 that the mines had been closed due to the extraordinary low prices for copper on the English markets, to inadequate capital and to a falling off of the quality of the ores produced lately from the mines.[55] In other words, the typical faults of which Carne lamented had been important factors in the closure of the mines at Cadia. Yet it cannot be said that Captain Josiah Holman had not done sufficient to explore the resource ahead of existing stopes, as demonstrated by his 1868 report. Nor is it possible to accuse Captain Christoe of not determining the correct smelting procedures for both oxide and sulphide ores and the judicious mixing of both ores to assist in the smelting process, so adequately described by the wandering reporter for the Sydney Mail in 1865.[56] The major factor in the temporary closure of the mine in this case appears to be the drastic decline in the international market rather than the need to raise more capital, a conclusion supported by the continuation of the Company and the later reopening of the mines once prices improved.

[54] J E Carne, *Copper Mining* 1908, p. 21-22.
[55] B. A. French, 'Extracts from the Directors Reports of the Scottish Australian Mining Company, 1868-1909', September 2000. unpaginated.
[56] Sydney Mail, 16 September 1865.

3. SITE SURVEY.

Site survey of the site of Smelter No. 1 was undertaken in June and August 2000, by Edward Higginbotham, Kevin Hickson, Martin Lawler and Tim Adams. Detailed plans and photographs have been included in a previous report.[57] The site is recorded as Inventory Number S114 on the plans and in the Inventory of Sites (Figure 3.1).

The site of smelter No. 1 is recognised largely as a scatter of slag, the waste product of the smelter. There is very little structural evidence visible on the surface, except for one of two brick or stone footings, which are insufficient to indicate the extent of nature of below ground remains. In additional there are traces of one or more working floors, covered with mullock and slag. On the eastern side of the smelter site is an alignment of stone footings, running north to south, associated with a raised platform at its northern end. This platform may be the building indicated on the plan of PGL 23, dated 1936. It may possibly be the assay office, which had slag walls, as described in Josiah Holman's report of 11 June 1868.

While most above ground remains of the smelter site have disappeared, substantial below ground remains survive were found to survive intact during the archaeological excavation.

[57] Edward Higginbotham & Associates Pty Ltd. Historical and archaeological assessment of Cadia Village in advance of the proposed mining of Cadia Quarry, Cadia, NSW. Cadia Holdings Pty Limited. 2000.

4. RESULTS OF ARCHAEOLOGICAL EXCAVATION.

Archaeological excavation of the subject site was completed by a small excavation team between 16 July and 17 August 2001.

The aim of the archaeological investigation was to locate and record archaeological features and to recover the archaeological significance of the site of Smelter No. 1 prior to final development of the Cadia Hill Mine.

4.1. Techniques of investigation.

The site of Smelter 1 was known by slag deposits, brick scatters and several structural features visible on the surface (see Chapter 3). The approach adopted involved area excavation by mechanical excavator to determine the extent of archaeological remains. The machine was provided with a 1.8 metre wide bucket without teeth (mud bucket) to leave a smooth surface, thereby readily enabling the recognition of any archaeological features. The investigation involved the mechanical removal of overburden and exposing an area of approximately 70 by 90 metres. Ranging in depth from several centimetres to around 1.5 metres, the overburden consisted of topsoil and silt accumulations and, in the lower western area, a substantial slag layer (Plate 4.98). These deposits overlay the remains of Smelter 1. Topsoil was also mostly removed to reveal features cut into the subsoil. Time constraints allowed the removal of rubble fill from only two furnaces (Furnaces 1 and 2) using a backhoe. The site was fully recorded, planned and photographed.

4.2. Excavation Results.

The excavation revealed nine primary structures (Figure 4.1, Plates 4.1 to 4.9). These include the main Smelting Hall with five furnaces, two additional furnaces, the flue system, several ancillary buildings, a retaining wall, two drains and two probable ponds. It may be noted here that all bricks were sandstock (flat or with rectangular frogs) and the stone used was either a local Silurian siltstone or slag. The former occurred predominantly as rubble but for wall facings the blocks were roughly dressed.

4.2.1. Soil Types.

The natural soil profile on which the smelter complex was built comprised a dark grey humic topsoil (A1) over a cream inorganic topsoil (A2) above natural grey clay with yellow mottling or red patches (B horizon). The site sloped to the west with the level of the A1 topsoil dropping approximately 8 metres over the width of the site, namely 60 metres.

4.2.2. Smelting Hall (Structure 1).

The Smelting Hall superstructure was represented by large post-holes of which several contained remnant bush timber uprights (Figures 4.1 and 4.2, Context 048). Not all post-holes could be located within the time available and several features are probably Hall post-holes (062, 063, 079, 080). The Hall was a rectangular building 19 by 19.5 metres (62 by 64 feet) wide and close to 40 metres (131 feet) long. Crooked post lines account for width variation and it appears that the 60 by 125 feet dimension given by Holman in 1868 was only an approximation of the size of the building, not an actual measurement.

Since not all post-holes were located, the configuration is not certain and consistency has to be assumed for distances between posts. Six uprights or posts (numbered 1 to 6 from the north) are indicated at the west end, with the largest gaps between Posts 1 and 2 (4.5 metres) and Posts 5 and 6 (4 metres). The number of posts or uprights along each longitudinal row appears to vary. Gaps of around 5 - 6 metres (16 - 20 feet) on the line extending from Post 1 suggests 8 posts in total, while the distance of 7 - 7.5 metres (23 - 25 feet) between posts on the line of Posts 2 and 5 suggests 7 posts, and just under 4 metres (12 feet) on the line of Post 6 suggests 12 posts.

Accommodating the furnaces could account for the wider spans along the lines of Posts 2 and 5, and more posts along the line of Posts 1 and 6 probably were needed to bear the load of the centre part of the building. With an even number of posts across the width several roof configurations are possible. If entirely hipped it was either symmetrical with the ridge not directly supported by uprights or asymmetrical with the lines of Posts 3 or 4 supporting the ridge. Another possibility is a hipped roof along the central area with the wider gaps along the north and south representing use of skillion roofs perhaps set at a lower level to ventilate the roof cavity above the furnaces.

4.2.2.1. Furnace 1.

Located at the west end of the Smelting Hall, Furnace 1 was 9.15 metres (30 feet) in length, the longest furnace and different in shape from the other reverberatory furnaces, since the ash-pit was placed at the end of the firebox and not at the side, as in all other cases. The furnace consisted of two sections each 15 feet long with a brick wall 23 cms (9 inches) wide dividing the cooling vault under the hearth from the firebox and ash-pit. The cooling vault measured 3.55 metres (11 feet 8 inches) wide with stone walls of varying widths (east 91 cms, north 51 cms, west 107 cms increasing to 114 cms at lower courses).[58] The east wall had three courses of brick laid into the inner lip, no doubt the springing of the arch itself, and a brick wall abutted much of the inner face of the west wall of the vault. At this point the cavity width was 91 cms (3 feet) widening to 132 cms at the north end.

The firebox and ash-pit were 3.25 metres (10 feet 8 inches) wide with stone walls of three or four courses and an average width around 55 cms. The firebox was at the north end, the ash-pit at the south with three stone steps set in the south-east corner providing steep access to the floor. The junction of the firebox and the ash-pit was indicated by a change in wall thickness. The box drain pierced both sides of the ash-pit through holes in the stonework, partially surrounded by brick, and drained the water through the ash-pit itself (see Box Drain, Structure 1.02). Parts of the floor of the ash-pit survived (733.05 AHD), mainly a soft, sandy shell lime mortar with cobblestones. This mortar was also used to bed and bond the stone walls, which throughout survived to a height of 110 cms. In the south firebox and ash-pit, the floor was covered with 8-9 cms of yellow-brown soil with large quantities of wood ash and charcoal. No brick superstructure survived on top of the firebox or ash-pit walls and in the hearth area itself only flat sandstocks of 5.7 by 10.8 by 22.9 cms (2 1/4 by 4 1/4 by 9 inches) were evident.

4.2.2.2. Furnace 2.

Furnace 2 shows some variations from Furnace 1. The firebox was located at the south end of the furnace hearth, while the ash-pit was located to the side of the firebox, not at its south end, as in Furnace 1. The firebox had no wall between it and the cooling vault, which would have been arched over in brick. The overall length of the reverberatory furnace was 8 metres (26 feet 3 inches). The furnace outline was 3.9

[58] For Imperial equivalents see Conversion Table, page ......

by 5.3 metres (12 feet 9 inches by 17 feet 4 inches) with stone walls 137 cms (4 feet 6 inches) wide. Along the inner lip of the stone side walls and contiguous with the brick arch remnants of the vault was a line of brickwork 58.5 cms (23 inches) wide on both sides. At the south end, only a remnant of brickwork of the arched vault survived, 18 cms (7 inches) wide. Four courses were evident. A line of bricks also was situated at the northern end of the vault, again part of the arch. The cooling vault measured 1.22 by 4.1 metres (4 feet by 13 feet 6 inches).

The southern chamber measured 2.6 by 4.3 metres (8 feet 6 inches by 14 feet) with the firebox and ash-pit differentiated by stone walls of different widths. The ash-pit wall ranged between 33 and 38 cms (13-15 inches) wide, the firebox wall was constant at 61 cms (2 feet) and both were 134 cms high (just under 4 feet 5 inches). On top of the larger wall, three courses of bricks with iron tie-rods was all that remained of the firebox superstructure. The firebox portion of the chamber was 152 by 175 cms (5 feet by 5 feet 9 inches), the ash-pit portion 183 by 190 cms (6 feet by 6 feet 3 inches). Five steps provided access to the ash-pit at a less extreme angle than those in Furnace 1. Like Furnace 1 the stone walls were bedded and bonded with a soft mortar used also to bond floor cobbling, though in this instance it was not sandy but appeared to be either the A2 topsoil or B clay mixed with shell lime. A difference of 4 cms between the floor levels of each chamber seems insignificant, and taking the average at 733.5 AHD the Furnace 2 floor was set 45 cms higher than the Furnace 1 floor. Immediately over the firebox and ash-pit floor was 30 cms of soil rich in charcoal. As far as could be determined the bricks used in Furnace 2 were exclusively flat sandstocks of 5.7 by 10.8 by 22.9 cms (2 1/4 by 4 1/4 by 9 inches). The large adjacent pit on the south side of the firebox and ash-pit chamber was filled with rubble in clay through which the box drain (Structure 1.02) had been cut.

4.2.2.3. Furnace 3.

Although severely damaged by demolition and robbing, Furnace 3 was similar in design and size to Furnace 2. Measurements are approximate, with the overall length of the furnace including firebox being about 7.85 metres (25 feet 9 inches) The furnace outline appears identically sized at 3.9 by 5.3 metres. Wall widths of the furnace are not known, but there is a difference in the stone walls of the firebox and ash-pit, which may also be slightly smaller at about 2.4 by 4.1 metres. The firebox wall reduces from 72 cms wide along the east side to 47 cms along the south (the Furnace 2 width was constant at 61 cms wide) and the abutting ash-pit wall is also narrower at 30 cms (12 inches). A part of the firebox superstructure survived as several courses of bricks and iron tie-rods. The longest of these rods measured 2.74 metres (9 feet). The remainder of the structure was stonework, bonded with a weak mortar, as before.

Within the furnace it appeared that parts of the hearth floor were intact. A patch of bricks laid flat with stone visible below occurred in the north-west corner, and a bright yellow fired material with associated brickwork was situated along the east side. Time did not permit excavation of the interior but it is likely that the furnace had a cooling vault, but it is not known whether it was separated from the firebox by a brick wall as in Furnace 1. Like the other furnaces, only flat sandstocks of 5.7 by 10.8 by 22.9 cms (2 1/4 by 4 1/4 by 9 inches) were evident as remnants of the superstructure. As with Furnace 2, the large pit on the south side of the firebox and ash-pit was filled with rubble in clay, but there was no clear cut by the Box Drain (Structure 1.02), although it passed through the pit. The pit therefore appears to be contemporary with the drain and may best be interpreted as the foundation trench for the furnace itself.

4.2.2.4. Furnace 4.

Demolition and robbing also inflicted major damage on this furnace and again time did not permit excavation of the interior to determine whether or not a cooling vault was present. The shallowness of the stone wall footings suggests it was not present in this example. The stone wall lines of the furnace were filled with rubble and at the south only the firebox was evident, with none of the ash-pit stonework surviving. However, in shape and dimensions Furnace 4 closely compares with Furnaces 2 and 3. The overall length was about 7.7 metres (25 feet 3 inches), the furnace outline around 4 by 5.3 metres and the firebox and ash-pit about 2.5 by 4.5 metres. The firebox wall widths were identical to those in Furnace 3, 72 cms wide along the west and 47 cms along the south (though the latter wall was 10 cms shorter here). Part of the firebox superstructure also survived, again several courses of bricks with iron tie-rods of which the longest was 2.95 metres (9 feet 8 inches).

Within the furnace outline was a compact crushed brick-like material, coloured red-purple by exposure to extreme heat and obviously part of the lower levels of the furnace hearth or floor. Investigation of the down-take (Structure 4.06) revealed that the rubble-filled wall footing trench along the east wall was just 40 cms deep with a very hard, orange-red clay below.

The brickwork of Furnace 4 was mostly of flat sandstock of 5.7 by 10.8 by 22.9 cms (2 1/4 by 4 1/4 by 9 inches) but included sandstocks with rectangular frogs, mostly of the same size, but including a slightly thicker type (6.4 cms or 2 1/2 inches). As with Furnaces 2 and 3 the large pit located south of the firebox remains was filled with rubble in clay but revealed no cut by the Box Drain (Structure 1.02). The pit therefore appears to be contemporary with the drain and may best be interpreted as the foundation trench for the furnace itself.

4.2.2.5. Furnace 5.

Located at the east end of the Smelting Hall, Furnace 5 was also severely damaged by demolition and robbing, but has its ash-pit to the side of the firebox, as in the layout of Furnaces 2, 3 and 4. It is slightly longer than the other furnaces with an overall length around 8.6 metres (just over 28 feet). The furnace outline is 6.1 metres (20 feet) long with a width around 3.4 metres (11 feet). The latter measurement assumes that a line of features along the west side represents the positions of buckstays set through tie-rods projecting from the furnace wall. Preservation was best along the east side, where the outer brick wall and a portion of an inner curving brick wall survived. The interior of the furnace consisted of stone rubble and a red crushed brick-like material affected by heat. This appears to be the lower part of the hearth floor. A test-trench dug by machine indicated that the effects of burning and heat continued to 80 cms or more, with no evidence for a cooling vault.

The firebox partially survived, but the ash-pit structure had been entirely robbed. The firebox measured 1.98 by 2.44 metres (6 feet 6 inches by 8 feet) with internal dimensions of 1.37 by 1.6 metres (4 feet 6 inches by 5 feet 3 inches). The internal face of the brickwork was highly eroded and covered with a layer of slag like material. In both furnace and firebox, flat and rectangular frogged sandstocks were used, but cream coloured fire bricks were used on the internal face. Unlike Furnaces 1 to 4, there are no stone footings to the furnace or fire box. Along with the usual tie-rods the brick work held several iron saddle bars set parallel with the firebox length, and an iron lintel plate supported the wall above the access from the ash pit. Unlike the other furnaces, there was no large pit south of the firebox and the Box Drain (Structure 1.02) did not extend to Furnace 5.

4.2.2.6. Perimeter Wall (Structure 1.01).

Along the south perimeter of the Smelting Hall was a section of stone and slag wall (056). It survived only as a single course around 50 cms wide and 8.3 metres long, but a cut continuing east suggested it was originally longer. This feature ran along the outside of the post line of the Smelting Hall and clearly suggests that this part of the Hall was walled to some height. The purpose of the wall is unclear, although other parts of the Hall may have had short section of stone or brick walling. Some of the stonework included slag, indicating that the wall was constructed after the commencement of smelting at Cadia.

4.2.2.7. Box Drain (Structure 1.02).

The Box Drain (Structure 2.01) ran downhill in a linear trench (047) through pits or footing trenches of Furnaces 2, 3 and 4. It ran through the ash-pit of Furnace 1, then continued towards the Workshop Building (Structure 6). Situated well within the Hall its function was to remove ground water from the ash-pits of the furnaces. Most of the drain was brick with rectangular frog with a channel of 20 cms width and 30 cms depth capped in places with slabs of slag. Two sections were made of stone where the drain approached Furnace 1. The side walls of the ash-pit of Furnace 1 were trimmed with stone and brick rubble where the drain passed in and out. With the entry above floor level and the exit at floor level the ash-pit became part of the drain.

The Box Drain was sealed by the clay work platform of the Smelting Hall (see below). The fact that slag is used in parts of the drain indicates that smelting had commenced before the Smelting Hall was completed.

4.2.2.8. Work platform and pavements.

The natural westward slope of the site down to Cadiangullong Creek required that the Smelting Hall be terraced into the slope. At its eastern end there is a clearly visible cut into the hill slope, while at the lower western end of the Hall, the working surfaces required the addition of fill to provide a work platform around the furnaces. A mix of three natural soil types, with A2 topsoil and B clay predominant over humic A1 topsoil, much of this fill would have been sourced from excavations for furnace foundations. Laid over the A1 topsoil and features such as the post-holes of the Hall and box drain, a platform with a drop of just under two metres from the east to west was constructed. At the west end it reached a maximum depth around 1.2 metres (4 feet) and ended at or before Structure 6 at a lower level. There was no evidence for a retaining wall. The fill surrounded the posts of the Hall and upper parts of furnace foundations, and on it were laid the brick and cobblestone pavements used as walkways and working surfaces. Cobbles (051) were found between Furnaces 1 to 4, along the north side of Furnace 3 and adjacent to Furnace 5. Expanses of brick pavement (059) occurred on the north of Furnaces 3 to 4 and a small section north of Furnace 2. The work surfaces did not survive well around Furnace 1, while a surface of redeposited clay was used around Furnace 5, except on its east side. Near the centre of the north wall a feature incorporating bricks laid flat (065) may represent steps up to the Hall platform. Several features at pavement level near Furnace 4 are of unknown purpose (074, 075, 076).

4.2.3. Furnace 6 and Building (Structure 2).

The building (Structure 2) housing Furnace 6 included adjacent brick pavements partially enclosed by a stone and slag wall with a timber superstructure. The latter was indicated by two lines of post-holes approximately 18 metres long and 7.5 metres apart. The former dimension is similar with Holman's description of a detached furnace shed, 60 feet (18.29 metres) long, but its documented width of 50 feet (15.24 metres) is basically double the distance between the two post lines. It seems most likely that Holman was describing the building over Furnace 6. The two surviving lines of posts therefore only represent part of the roofed area.[59]

The survival of the hearth floor and lower parts of the side walls means that Furnace 6 is the best preserved and repeats the basic design of Furnaces 2 to 5 with the ash-pit set to the side of the main axis. The overall length is 7.7 metres (25 feet 3 inches) with a furnace outline of 4.12 by 5.38 metres (13 feet 6 inches by 17 feet 8 inches). The perimeter walls were stone and slag bonded with a very hard lime mortar. Beneath the hearth there was a cooling vault, arched over with stone, over which the hearth was bedded. Adjacent to the firebox, this vault was faced with a brick arch under what would have been the fire bridge. The vault was filled over with a fired and cemented sand bed, levelled to form the hearth floor, no doubt constructed in the usual manner of reverberatory furnaces. On either side of the hearth the side walls of flat and rectangular frogged sandstock bricks survived to a limited height. Measuring 36.5 cms wide (14 inches) wide, these curving walls formed an ovoid hearth 2.74 metres (9 feet) at its widest and 4 metres long, with open ends and a triangular tap-hole central on the west side.

[59] Josiah Holman, Report. 11 June 1868.

The stone walls of the firebox were 41 cms (16 inches) wide and joined with the west furnace wall. The firebox measured 2.05 by 2.3 metres (6 feet 9 inches by 7 feet 6 inches) with an inner skin of brickwork 28 cms (11 inches) thick, giving internal firebox dimensions of 1.45 metres (4 feet 9 inches) square. Tie-rods occurred all round the furnace and firebox walls and the latter also held three iron saddle bars. The larger indicated the fire grate was set basically at the same level as the hearth floor. The ash-pit wall was stone and the cavity slightly smaller than the firebox, though later enlargement is suggested by use of mud mortar for a small section of stone wall set at a higher level on the east side. At the base of the north wall of the firebox was a small cavity through which water constantly flowed during excavation. This suggests a drain possibly represented by a linear cut (085) running downslope to the north-west.

A perimeter wall of stone and slag, 46 cms (18 inches) wide, partly abutted the north-east corner of the furnace. This north wall measured 4.65 metres (15 feet 3 inches) long and turned at a rightangle to a side wall measuring 8.25 metres (27 feet) long on the east side. Two pieces of bush timber were bonded into the side wall, possibly plugs for attachment of timber fittings along the wall. A brick pavement (082, 087) was laid in this attached stone walled building, and continued in front of the furnace. The bricks were laid on a bedding of material similar to the furnace floor but with fine gravel mixed through. The bricks were both flat and rectangular frogged sandstocks, mostly 6.4 by 10.8 by 22.9 cms (2 1/2 by 4 1/4 by 9 inches) but including some 5.7 cms (2 1/4 inches) thick. Some had vitrified surfaces which, if not due to over-firing, indicate re-use of furnace brickwork. Gaps in the brickwork on the east side of the furnace indicated the positions of buckstays. One part of a buckstay survived on the west side of the firebox and indicates that timber was used, although it is surprising that it had the strength to secure the furnace structure for any length of time. A combination of charcoal and very humic fill in a series of buckstay positions along the east side of the furnace strongly suggest the use of more than one timber buckstay on this furnace. However, several remnants of iron buckstays were found in the vicinity of Furnace 6.

On the west side of Furnace 6, it was evident that the pavement bedding and the exterior furnace wall were both set over a deposit of slag (085). The precise relationship between slag and furnace was not determined and the eastward extent of the deposit not traced. However, the distance to which it extended west and south suggests it is not backfill of the furnace foundation trench and probably was in situ before the furnace was built.

The location of slag under the furnace wall must indicate that this furnace was constructed after the commencement of smelting at Cadia. The hardness of the bonding of the stonework also suggests a slightly later date than the other furnaces. Furnace 6 is therefore possibly the one to have been built in 1865, as described by the wandering reporter for the *Sydney Mail*.[60] It was clearly the furnace to be given a new hearth in 1868.[61]

Running parallel to the east side of Furnace 6 and its masonry building was a large and long feature filled with a grey sludge and silt layers (090). It appears to have been a water storage feature or a settling pond for liquid wastes flowing from further up the slope, possibly from the vicinity of Furnace 7. The pond would have diverted any water around Furnace 6 and its enclosing building (Structure 2), since the pond extended further to the north of the furnace.

4.2.4. Comparison of furnace size and dimensions (Furnaces 1 to 6).

Furnaces	1	2	3	4	5	6
Firebox - external width	2.9	2.13	2.3	2.23	1.98	2.05
Firebox - external length	2.05	2.36	2.4	2.15	2.13	2.31
Firebox - internal width	1.8	1.52	1.55	1.5	1.37	1.45
Firebox - internal length	1.8	1.75	2	1.65	c. 1.6	1.45
Furnace - external width	3.55	3.89	c. 3.91	c. 3.94	c. 3.35	4.12
Furnace - external length	4.57	5.3	c. 5.3	c. 5.3	c. 6.1	5.38
Hearth - internal width	-	-	-	-	-	2.73
Hearth - internal length	-	-	-	-	-	4
Down-take - external width	1.32	1.3	c. 1	1.32	1.83	c. 1.2
Down-take - external length	1.32	-	-	-	1.93	-
Down-take - internal width	0.66	c. 1	c. 0.7	c. 1	0.7	-
Down-take - internal length	0.66	-	-	-	0.76	-

Table 4.1. Dimensions of Furnaces 1 to 6. Note: The length is always parallel with the longitudinal axis of the furnace, the width at rightangles to this axis. Measurements can only be approximate, due to the poor surviving condition of most of the furnaces.

60 Sydney Mail, 16 September 1865.
61 Josiah Holman, Report. 11 June 1868.

The above measurements are summarised in square metres:

Furnaces	1	2	3	4	5	6
Firebox - overall area	5.95	4.60	5.52	4.79	4.22	4.74
Firebox - internal area	3.24	2.66	3.10	2.48	c.2.19	2.10
Furnace - overall area	16.22	20.62	c.20.72	c.20.88	c.20.44	22.17
Down-take - internal area	0.44	-	-	-	0.53	-

Table 4.2 Dimensions of Furnaces 1 to 6, given in square metres.

In general calcining furnaces would have been larger than smelting furnaces while refining furnaces would have been of even smaller dimensions. Of those furnaces actually in the Smelting Hall, Furnace 5 is the largest, while Furnaces 2 to 4 are of lesser size. Furnace 1 is the smallest. This would suggest that Furnace 5 is a calcining furnace, Furnaces 2 to 4 are smelting furnaces and Furnace 1 is a refining furnace. This is confirmed by their overall characteristics and also by the fact that the ore was always processed in a manner that enabled easy of handling, namely the commencement of the smelting process at the top of the slope and ending at the lower levels.

4.2.5. Structure 3. Furnace 7.

Furnace 7 is located upslope and east of Structure 2. It is entirely different to Furnaces 1 to 6 in having a dodecahedral form. Set around a hexagonal core of bonded stonework, 1.52 metres (5 feet) wide, were six rectangular brick chambers set between triangular infills of bonded stone. The chambers had the same width of 1.07 metres (3 feet 6 inches), but lengths alternated around the stone core. The three with intact lengths measured 94 cms, 94.5 cms and 151 cms, suggesting intended lengths of 3 feet and 5 feet. Across one of the longer chambers were three iron saddle bars 2.54 cms (1 inch) square, on which were laid fire bars for the grate also 2.54 cms square and mostly 160 cms (5 feet 3 inches) long. The longest measured 173 cms (5 feet 8 inches). The same fire bar / saddle bar arrangement was less well preserved in the north chamber. One of the smaller chambers was excavated to reveal the survival of 11 brick courses to a height of 75 cms, two cylindrical saddle bars of 3.8 cms (1 1/2 inches) diameter, set across the chamber, and a floor of very hard, orange clay (surface 738.43 AHD). As in other furnaces, the brick-like nature of this clay is probably related to very high temperatures.

Furnace 7 was built into the slope. On the east side the structure was laid into a cut with backfill around, on the west the brick and stone work sat on a bed of mortar on A1 topsoil (surface 738.33 AHD). The bonding material used throughout was soft lime mortar found in the Smelting Hall furnaces. It is assumed that all six chambers were originally equipped with fire bars laid on square or circular saddle bars, since all contained deposits of ash and charcoal. It is also assumed that there was a furnace floor above the fireboxes and that this furnace vented through a chimney unconnected to the flue system. The furnace would have had a similar capacity to Furnace 6, assuming the walls were of a similar thickness.

At the base of two small test pits were found portions of rectilinear cuts but it is not certain if they represent post-holes for a timber superstructure. The detached shed of 25 by 35 feet described by Josiah Holman as covering a calcining furnace would comfortably encompass this structure.[62] The adjacent stone wall (Structure 5) might have played a support role along the east side but no post-holes cutting the A2 soil around Furnace 7 were located.

4.2.6. Flue System (Structure 4).

The flue system consisted of the main flue (Structure 4), a pit with one side wall of stone (Structure 4.01), associated box drain (Structure 4.02) at the downslope end and side flues (Structures 4.03-4.08) joining Furnaces 1 to 6 with the main flue. The main and side flues used both flat and rectangular frogged sandstocks.

The main flue was traced over a length of 65 metres (213 feet, 71 yards), considerably longer than the 'about sixty yards' reported in 1865.[63] Beginning north of Furnace 1, it ran upslope to disappear under the Old Cadia Road alignment (present mine road). Hence the site of the stack could not be located. The flue was a double brick barrel vault bonded with the soft lime mortar found in the Smelting Hall furnaces. Set in a cut with soil and brick rubble backfill, its exterior width was 1.68 metres (5 feet 6 inches) and the interior 1.3 metres (4 feet 3 inches). Since the top of the vault had been destroyed along the entire length the height is not certain. At the west end an inner surface not far from the centre stood about 1.75 metres (5 feet 9 inches) above floor level, suggesting an original internal height of 6 feet. Similar to the orange-red

62 Josiah Holman, Report. 11 June 1868.
63 Sydney Mail, 16 September 1865.

brick-like material found elsewhere, the floor was heat affected clay (natural B Horizon). Where revealed the floor was sealed by silt layers under slag and soil.

At the downslope end, the main flue commenced in line with the east side of Structure 4.01, delineated by a stone wall (052), set along the south side of a large pit (053). The end wall of the flue was marked by robbed out brickwork, which had left a ghost in the soil. It is not certain if the flue was closed or open ended. Although this makes it uncertain if Structure 4.01 directly related to operation of the flue, it seems significant that the flue floor and base of the stone wall and the pit were at the same level (735.52 AHD). The stone wall was 46 cms (1 feet 6 inches) wide, 3.05 metres (10 feet) long, 1.57 metres (just over 5 feet) high and bonded with soft lime mortar. The pit was 2.21 metres (7 feet 3 inches) wide and slightly longer than the stone wall where its cut along the north side was contiguous with the flue cut. The depth of the pit was 91 cms, excluding topsoil (A1 and A2 Horizons). The fill was slag and building rubble contained in a silt matrix.

From the west end of the stone wall, a brick box drain (Structure 4.02, 045) ran westward downslope for at least 7 metres. With three courses along the sides the drain was 35.6 cms (14 inches) wide and 28 cms (11 inches) deep with a single course of capping bricks laid crosswise. As far as could be determined only flat sandstocks were used, measuring 6.1 by 10.8 by 22.9 cms (2 3/8 by 4 1/4 by 9 inches). They are slightly thicker than the flat sandstocks elsewhere (2 1/4 inches). As indicated by the cut, the drain did not connect with the pit (053), but aligned with the end of the stone wall (052). Although no post-holes were found, the pit was presumably covered to prevent filling by water. A patch of a humic soil in the drain backfill adjacent to the wall may represent a downpipe from a roof structure, which may have been an extension of the Smelting Hall roof.

All but Furnace 7 were connected to the main flue by smaller flues (Structures 4.03 to 4.08, numbered in order from Furnaces 1 through to 6. These were also double brick barrel vaults set in cuts with backfill laid over. The junction between the main flue and the flue (Structure 4.06) from Furnace 4 was excavated to show a flue height of 132 cms (4 feet 4 inches) and a two ring arch built over the entry to the main flue. All the branch flues are likely to have been the same height and it may be assumed that arches occurred at all the junctions to the main flue. Partial excavation of the side flue (Structure 4.07) from Furnace 5 revealed slag lining on the walls and floor, recalling the 1865 report that some of the metal was carried off as vapour, which yielded a large percentage of copper when cleaned out and re-smelted.[64]

The side flues were connected with the furnaces through a down-take, a rectilinear brick chamber, situated at the north-east corner of Furnaces 1 to 5 and at the south-east corner of Furnace 6. The best preserved were in Furnaces 1 and 5. The former showed a square chamber of double brick with an interior cavity 66 cms (2 feet 2 inches) square and an exterior size of 1.32 metres (4 feet 4 inches) square, the latter being the same as the height of side flue (Structure 4.06). The flue chamber of Furnace 5 was partly robbed, but rectangular, with a width of 1.83 metres (6 feet) and length of 1.93 metres (6 feet 4 inches). The north end was open at ground level, which may indicate an inspection access. Assuming the north wall was equivalent in width to the south wall, the interior cavity was 0.7 by 0.76 metres (2 feet 3 inches by 2 feet 6 inches). The Furnace 6 down-take was not evident at ground level and was probably totally robbed out. The others had been severely damaged by robbing. Excavation of the Furnace 4 down-take showed an exterior width identical to that of Furnace 1 (132 cms) and a thick slag deposit around the interior. The Furnace 2 down-take shows a very similar exterior width. The Furnace 3 down-take appears to have been slightly smaller and perhaps rectangular with a width around 1 metre (3 feet 4 inches?).

Several of the side flues showed definite and probable modification or alteration. A stone wall partially closed the entry of the side flue (Structure 4.06) into the main flue and suggests an attempt to reduce or dampen the draught from Furnace 4. Flue (Structure 4.07) out of Furnace 5 was partly dismantled to construct a brick wall running north-south and turning east at the north end. This wall may have been part of the Smelting Hall east wall and it is not clear whether it still allowed the flue from Furnace 5 to work. There is evidence to suggest that the flues out of Furnaces 2 and 3 were also closed at some stage. Near the junction of the side flue (Structure 4.04) of Furnace 2 and the main flue was a feature, contiguous on one side with the edge of the flue cut (064). Partial excavation revealed a narrow, rectangular cut with the flue vault cleanly removed and backfilled with rubble. Both the regularity and size of the cutting do not suggest a robber trench, but the deliberate blocking of the flue. Although not excavated, a similar feature (069) was situated near the junction of the side flue (Structure 4.05) of Furnace 3 and the main flue. Assuming deliberate blocking of the flue, Furnaces 2 and 3 could not have operated in the final stage of smelter production.

4.2.7. Retaining Wall (Structure 5).

[64] Sydney Mail, 16 September 1865.

The retaining wall (Structure 5) is constructed of random rubble stone and runs north-west to south-east, just east of Furnace 7 (and may have helped support a superstructure covering that furnace). With an average width around 40 cms (15-16 inches), the wall was extant in two sections of 23.25 metres (76 feet 3 inches) in the south and 7.85 metres (25 feet 9 inches) in the north. It is not known if the wall has been robbed or if a gap of 3.1 metres (10 feet 2 inches) between the two sections might mark a roadway. The remaining height averaged around 70 cms (2 feet 3 inches) though this may not be the original height. The north section had been robbed to leave just a single course. The wall was bonded with a soft lime mortar, as used in the Smelting Hall furnaces. On the upslope (east) side, A2 Horizon topsoil and B Horizon clay infilled the area behind the wall to create a long and level platform along the east side of the site and above Furnace 7.

4.2.7.1. Building (Structure 5.01).

The footings of a building were located abutting the stone retaining wall (Structure 5) which served as the footing of its west wall. Probably intended to be rectangular the building was in fact rhomboidal due to the side footings not being true. Like the retaining wall (Structure 5), the north wall footing had been mostly robbed and the north section of the east footing was recently destroyed by the laying of water pipes. Unlike the retaining wall (Structure 5), the footings of the building were made with stone and slag bonded with the very hard mortar, also evident in Structure 2 and Furnace 6.

The building was 9.22 metres (30 feet 3 inches) long and 5.5 metres (18 feet) wide with a wall thickness averaging 52 cms (20 inches). Whereas the retaining wall (Structure 5) had been set into the natural A1 Horizon topsoil, the footings of the building (Structure 5.01) were laid on top of it, and in following the westward slope the south wall footing increased in height to 71 cms (28 inches). The stratigraphic relationship between the footings and the fill laid behind the retaining wall (Structure 5) is not certain. While no trench cuts were observed the footings may have been laid flush with any trench cut.

On its west side, a remnant part of the wall of the Building (Structure 5.01) was built on the surface of the fill layer behind the retaining wall (Structure 5). It was a slag footing along the inside edge of the retaining wall (Structure 5). It measured 3.1 metres long with a maximum width and height of 46 cms (1 foot 6 inches). On its top surface was a layer of mortar with brick impressions, similar in width and length with bricks used elsewhere (11 by 23 cms or 4 1/4 by 9 inches) but the rectangular frog was a more developed and more precisely impressed envelope form. That none were found in the vicinity indicates wholesale robbing but more significantly the type occurred in no other structure. The well formed brick type and the hard form of lime mortar, as used on Furnace 6, but not on Furnaces 1 to 5 and 7, suggest that the building (Structure 5.01) and Furnace 6 are later in the construction sequence than Furnaces 1 to 5 and 7, including the retaining wall (Structure 5).

4.2.8. Workshops (Structure 6).

Situated downslope and west of Furnace 1 and buried by a thick deposit of slag, the workshop area (Structure 6) was a two-roomed timber building, preserved only to floor level. In each room the flooring was bounded on three sides by wall slots with a remnant brick structure set in the east wall. Each room was 6.4 metres (21 feet) long with a width of at least 3.8 metres (12 feet 6 inches). The full width of the building was not apparent, since the lower side wall was removed by later activities on the site, before deposition of slag. The rooms were divided by a central wall slot. The slots measured 18 cms (7 inches) wide and 11 cms (4 1/4 inches) deep. The walls were not set at rightangles, but irregular angles were also noted in the Smelting Hall post lines, the layout of the building (Structure 2) over Furnace 6 and the walls of Building (Structure 5.01). The floor surfaces in each room were different. There was a shell lime mortar and gravel floor, 4 cms thick, in the north room and a clay floor, 2-3 cms thick, in the south room. Across both floors were patches of ash and charcoal.

In the north room just parts of the base course of the brick structure in the east wall survived. It was essentially rectangular, measuring 1.45 by 2.75 metres (4 feet 9 inches by 9 feet) with an extension along the outside of the wall at least on the south side. It appears to have had two sections, each with a Y-shaped vent in which were deposits of ash and charcoal. It seems certain that these were small furnaces. A number of fragments of small ceramic crucibles were also found on the floor. The brick structure in the south room was better preserved with two courses of a rectangle of 1.37 by 1.84 metres (4 feet 6 inches by 6 feet) with walls 23 cms (9 inches) wide. The interior had rubble fill over a layer of ash and charcoal around 1 cm thick sitting on a brick floor. Flat and rectangular frogged sandstocks 10.8 cms (4 1/4 inches) wide and 22.9 cms (9 inches) long were used in both structures. However, those in the north room were exclusively 5.7 cms (2 1/4 inches) thick whereas those in the south structure were variously 5.1, 5.7 and 6.4 cms thick (2, 2 1/4 and 2 1/2 inches). Unless the different flooring types related to room function, the use of different sized bricks may suggest the two rooms were not constructed at the same time.

These two rooms are interpreted as workshop buildings. The presence of the footings of small furnaces, together with crucible fragments, suggest that this was the assay office, mentioned in 1861 and 1868. The dimensions of the building equate better with the dimensions of the building mentioned in 1868.[65]

4.2.9. Workshop (Structure 7).

A structure (Structure 7) was situated at the south-western edge of the Smelting Hall complex, south of the Workshops (Structure 6). Time did not permit full excavation The building was rectangular with a width of approximately 2.2 metres (7 feet) and a length of 5.2 metres (17 feet), divided into two areas. That on the west was indicated by stone rubble surface set in clay, measuring 2 by 2.44 metres (6 feet 6 inches by 8 feet). This surface was set on a bed of soft shell lime mortar and a thin layer of clay over A1 Horizon topsoil. The east area was characterised by an ash and charcoal deposit (029) roughly 2 metres (6 feet 6 inches) square with an extension to each side. Stone footings probably surrounded the ash and charcoal deposit, which may have been part of a furnace or hearth.

Leading away from the south-west corner of the charcoal area was a shallow channel (030) in redeposited clay along the edge of the stone area, with a fill of slag, stone and brick rubble and artefacts. This could be an erosion channel or perhaps drained the ash and charcoal area. Two possible post-holes were located, one (037) on the north side and another (031) on the south-east. although no additional features indicative of wall lines were found, it is likely that the structure was roofed over, possibly attached to the roof of Structure 6. A small patch of stones occurred just south-west of the clay and cobble surface, possibly indicating an extension of the yard surface

A feature that may be associated with Structure 7 was situated 2.75 metres (9 feet) upslope to the east. It was a rectangular pit of 1.6 metres (5 feet 3 inches) square and 12 cms deep with stones laid on the base.

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[65] B. A. French, 'Extracts from the Directors Reports of the Scottish Australian Mining Company, 1868-1909', September 2000. unpaginated.
Josiah Holman, Report. 11 June 1868.

4.2.10. Structure 8.

Structure 8 was represented by a large irregular pit, roughly. 2.5 by 3 metres (about 8 feet by 10 feet) in which four posts were standing. The post orientation was two, set 2 metres (6 feet 6 inches) apart on the west side and two, set 1.2 metres (4 feet) apart on the east side, with a gap of about 0.2-0.25 metres (9 inches?) between. This feature was not excavated but another bush timber was visible in the fill which consisted mostly of clay with some A1 and A2 Horizon soils present along with slag and silt banding.

4.2.11. Structure 9.

This structure was laid into the thick slag deposit covering nearby Structures 6, 7 and 8. It was sectioned by machine to reveal an area of redeposited clay 50 cms deep over an area of 1.3 by 2.2 metres with a brick footing along the east side. The footing was 40 cms high, six courses of unmortared bricks.. Only bricks with rectangular frogs were visible. The structure overlays the slag which covered Structures 6, 7 and 8 and must therefore be late in the sequence of occupation on the site.

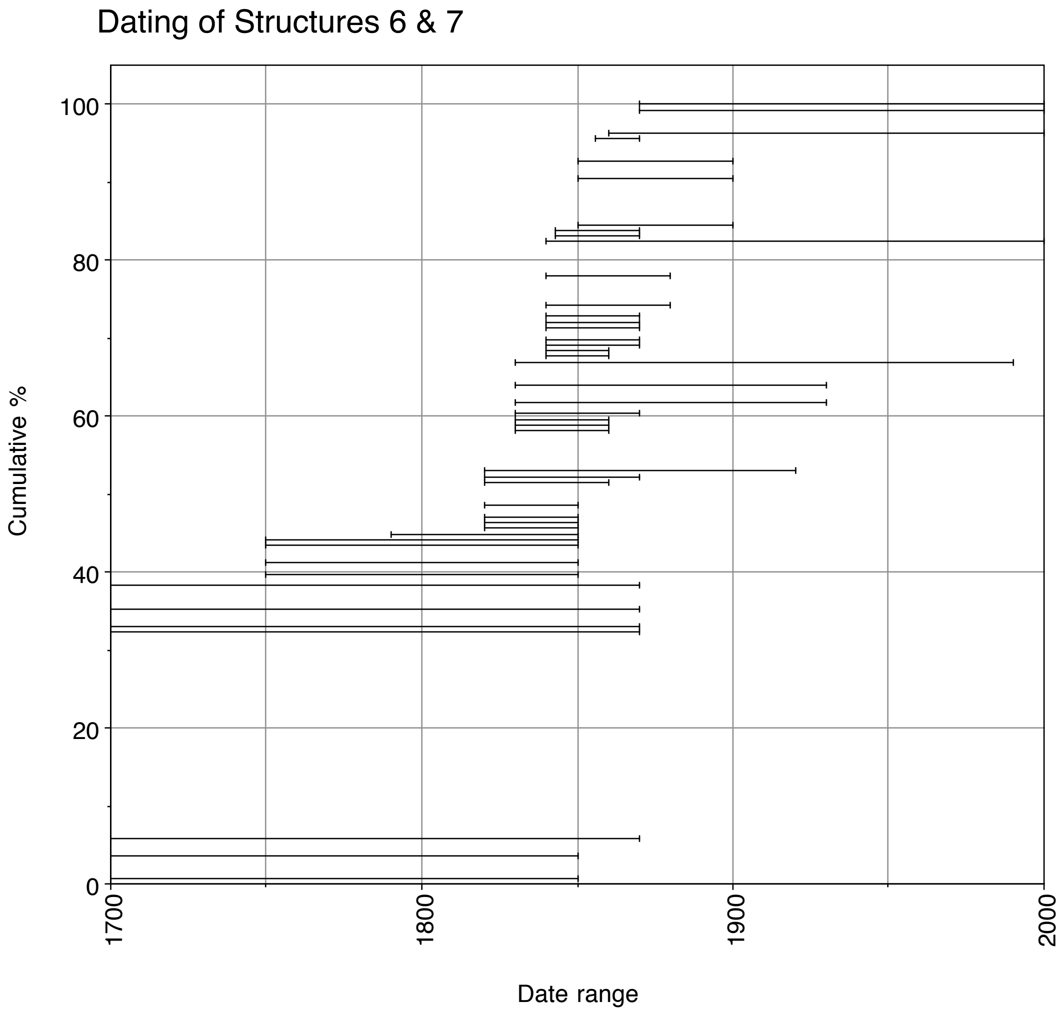
4.2.12. Demolition and Robbing.

After Smelter Number 1 went out of use, many of the cavities in the furnaces and flues have filled with silt and soil deposits, indicative of extensive soil erosion. Much of the brickwork of the flues, furnaces and other structures has also been robbed out in a very extensive manner. Where brickwork has not been removed, it is usually not in good enough condition for re-use or must already have been covered in a great depth of silt from soil erosion, for example in Furnace 5.

After soil erosion and robbing had taken place, many of the furnaces, flues and working floors were covered in slag. The extensive nature of this slag covering suggests that it was spread by machine in a final process of demolition. In section, the slag layer can be seen to have a surface, which could easily have been caused by heavy traffic over its surface. The irregular shape of slag overburden to the west of the site also reveals that it has been taken away for other purposes, like road metalling.

The absolute dating of soil erosion and silting, robbing and final demolition cannot be accurately established. The brickwork could have been used for later mining purposes, the construction of Smelter No. 2 or for the construction of nearby houses in the Village or surrounding farms. Robbing of brick ruins was far easier and cheaper than purchase and transport of bricks from the nearest brick kilns in Orange or Bathurst, and was probably the only option available except for major capital works.

4.3. Artifact analysis and dating.



Graph 4.1. The dating of artifacts from Structures 6 and 7, Smelter No. 1. The graph shows the date range of datable artifacts. Deposition of artifacts ceases around the 1870s, since there are no later introductions. For all these artifacts to be found in the assemblage, the latest date for occupation is the 1850s. Historical documentation indicates construction in the 1860s. The differences between the archaeological and historical data may be explained by assuming that items belonging to the 1850s remained in circulation to the 1860s.

Only small numbers of artifacts were located other than iron objects associated with the furnaces. These were mostly structural elements, but also included tools and equipment, such as paddles, rabbles, hammer, gads or chisels and a wheelbarrow. One of the most important finds was a possible section of a tramline with a flanged U shaped section, which would indicate the possible use of tramlines and trucks to transport the ore and matte around the smelting furnaces.

Other important finds included a number of crucible fragments from Structures 6 and 7, pointing to the presence of the Assay Office in this area of the site.

The dating of the artifacts from Structures 6 and 7 indicated that these structures were used from the 1850s to the 1870s. While the historical documentation provides more accuracy for the construction and dating of Smelter No. 1, nonetheless that fact that Structures 6 and 7 continued in use until the 1870s, but no later, indicates that they could not have been covered with slag until after this date. The slag was tipped over the sites of these buildings after the smelter went out of use, not while it was in service. Thus the Assay Office and Blacksmith's shop mentioned in historical documentation actually refers to these buildings, which we can now prove were in use and not covered with slag.

The complete artifact catalogue is located in Appendix 3.

4.4. Layout of Smelter No. 1 and its industrial processes.

The archaeological evidence points to the sequence in which industrial processes were undertaken in Smelter No. 1

The bonding material, a hard lime mortar, used in Furnace 6 and in the building (Structure 5.01) suggests that these two structures were built after the other structures of Smelter No. 1.

The earlier furnaces therefore appear to be Furnaces 1 to 5 and 7. Furnaces 1 to 5 are located in the Smelting Hall and were clearly built in one sequence and connected to the flue and chimney. Furnace 7 was not connected to the flue system and was constructed independently of Furnaces 1 to 5. The archaeological evidence does not itself indicate the relative chronology of Furnace 7 to Furnaces 1 to 5.

In the Smelting Hall, Furnaces 1 to 5 are built in a line, each one slightly lower than the other, in reverse numerical order, with Furnace 5 at the top of the Hall and Furnace 1 at the lower or western end. Normal practice in a Welsh Smelting Hall would be for the ore to go from a higher to a lower level during processing.

The dimensions of the furnaces vary. Of those furnaces actually in the Smelting Hall, Furnace 5 is the largest, while Furnaces 2 to 4 are of lesser size. Furnace 1 is the smallest (see dimensions in Tables 4.1 and 4.2). In general calcining furnaces would have been larger than smelting furnaces while refining furnaces would have been of even smaller dimensions.

The furnace dimensions suggest that Furnace 5 is a calcining furnace, Furnaces 2 to 4 are smelting furnaces and Furnace 1 is a refining furnace. This is confirmed by their overall characteristics and also by their order and level in the Smelting Hall.

This identification of use can be correlated with the historical documentation. Josiah Holman, in his report dated 11 June 1868, indicates that there are three smelting furnaces, one calcining and one refining furnace in the Smelting Hall. This ties in with the archaeological evidence, but Holman also mentions their state of repair. He indicates that the refining furnace and one smelting furnace are in working order, the rest requiring rebuilding from the foundations upwards. We can therefore assume that only Furnace 1 and one of Furnaces 2 to 4 were working. This is supported by the archaeological evidence for the state of the flues to Furnaces 2, 3 and 5, all of which appear to have been blocked or taken out of use. If only Furnaces 4 and 1 were working, this ties in with their identification as smelting furnace (Furnace 4) and refining furnace (Furnace 1).[66]

Furnace 6 is clearly identified with the smelting furnace which was given a new floor by 1868, while the other furnace is described as a calcining furnace by Josiah Holman.[67]

The state of the furnaces in 1868 and the similar state indicated by the archaeological evidence implies that little or no modifications to the furnaces took place after 1868. It is possible that the calcining furnace (Furnace 7), the two remaining smelting furnaces (Furnaces 4 and 6) and the refining furnace (Furnace 1) were used after 1868, since they provided the means whereby smelting of the ore could be taken

[66] Josiah Holman, Report. 11 June 1868.
[67] Josiah Holman, Report. 11 June 1868.

through a complete process, even without the other furnaces. There is historical documentation for smelting continuing in the 1870s and 1880s, through to the construction of Smelter No. 2 in 1889.

The Workshop (Structure 6) is most likely to be the assay office, identified in 1861 and 1868, while the Workshop (Structure 7) is probably the Blacksmith's Shop, also identified in 1868. Both these two buildings (Structures 6 and 7) appear to have gone out of use by the 1870s. The weighbridge with Avery weighing machines was not located.[68]

(See 5.4. Furnaces and smelting at Cadia - adaptations to local conditions).

[68] Josiah Holman, Report. 11 June 1868.

5. DEVELOPMENT OF THE WELSH COPPER SMELTING INDUSTRY AND FURNACE TECHNOLOGY.

5.1. The Welsh Copper Smelting Industry, 1580s to c.1700.

The establishment of the Australian copper mining industry principally depended upon Cornish mining expertise as well as Welsh smelting technology. This specialisation had arisen because of the location of abundant ores in Cornwall and Devon, while plentiful coal for smelting purposes was only available in South Wales, in the Swansea District.

The Welsh smelting industry commenced as early as the 1580s, smelting ores principally from the mines in Cornwall. The "Melting House" at Neath was ready for smelting ores from Cornwall in 1584 and Ulrick Frosse, a German, was placed in charge. German influence was also present at the Mines Royal, Keswick, Cumberland, which were developed after a Royal Patent was given to Thomas Thurland, Master of the Hospital of the Savoy (London), and Daniel Hoechstetter, a German, on 10 October 1564.[69]

Since the metalliferous ores of the United Kingdom were reserved to the Crown, it was necessary to obtain a Crown Grant or Patent for mining and smelting from the Crown. The Letters Patent of 10 October 1564 made provision for the Governors, Assistants and Society of the Mines Royal and gave to the Society the right to mine for gold, silver, copper and quicksilver in the Counties of York, Lancashire, Cumberland, Westmoreland, Cornwall, Devon, Gloucester, Worcester as well as Wales. The Mines Royal Society was confirmed by Royal Charter, dated 28 January 1604.

Another company, namely the Mineral and Battery Works Society was formed by Royal Charter on 22 January 1565 to mine and refine "Calamine Stone". Its governors were William Humphry, then Assay Master of the Royal Mint within the Tower of London and Christopher Shutz, of Germany, born at St. Annenberg, "Work Master" and highly skilled in the production of metal alloys. The Charter allowed the Society to exploit the "Calamine Stone" in any part of the United Kingdom, except in those areas granted to the Mines Royal Society. Its Royal Charter was again confirmed on 22 January 1604.

[69] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 24ff.

By 1670 both societies were to all intents and purposes amalgamated, since they shared the same governors, deputy governors and assistants. They remained under the same management until their dissolution in 1852. The "Battery Works" or "Melting House" of the Mineral and Battery Works Society was located at Neath, South Wales.[70]

In 1683, Sir John Pettus translated into English the Assays of Lazarus Eerckern, Chief Prover or Assay Master of the Empire of Germany. It explained the mining and smelting of copper, among other minerals, and described the holdings of the Mines Royal and Battery Works Societies.[71]

The Mines Royal Company started to smelt copper at Redbrook in Monmouthshire, South Wales in 1756-1758, under the management of Robert Place. (Copper smelters had in 1754 been constructed by Sampson Swaine, father-in-law of Robert Place, in the Parish of Entral in Cornwall. The smelters were later moved to Hayle in Cornwall, but were opposed by the Mines Royal Company, since they infringed upon their Royal Charter).[72]

Other companies began to establish smelting works in South Wales. These included the "Corporation of the Governor and Company of Mine Adventurers of England", founded by Sir Humphrey Mackworth in c.1699, but only receiving its Charter in 1704. On his own account, Mackworth had invested large sums of capital in developing the coal resources around Neath from 1695. He also built factories and other works for processing copper and lead at Melincrethryn (or Mellyn-gry-than), near Gnoll, Neath, including an old smelting-house, a Copper-house, a cleaning-room, a brick-room and a stamping-room. The Company had other smelting works in Cardiganshire.[73]

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70 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 57ff.

71 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 70ff.

72 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 74f.

73 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 81ff.

5.1.1. The smelting industry at Swansea, 1717 onwards.

The first copper works on the banks of the River Tawe at Swansea were erected by a Mr. Pollard and his son-in-law, Dr. Lane, in 1717. They were known as the Llangavelach Works.[74] Mr. Pollard held extensive copper mines on his estates in Cornwall. The copper smelting works were soon removed to Landore (or Landwr). Having been bankrupted by the South Sea Bubble, the works were sold to Richard Lockwood, Edward Gibbon and Robert Morris in 1827.[75]

Lockwood, Morris and Company moved their business from the Llangavelach Works upstream to the Forest Copper Works in 1727, possibly to gain easier access to coal, but also possibly because “the copper smoke” was proving a nuisance nearer to Swansea. The Forest Copper Works were leased by the English Copper Company in 1845, but remained idle.[76]

The White Rock Copper Works were located on the east bank of the River Tawe at Kylvey, near Swansea and were constructed in 1730.[77] This led to further development of the smelting industry on the east bank of the River Tawe. In 1755, Mr. Chauncey Townsend built furnaces and refineries at the “Middle Bank” Copper Works. A later historical source, dated to 1867, recorded that there were three conical furnaces at this site.[78]

Under joint management with the Middle Bank Copper Works were those of the Upper Bank Copper Works. Around 1800 these works were in the possession of Thomas Williams of Anglesey, who was considered to be the leading man in the copper trade. Thomas Williams joined the Stanley Smelting Company and a new lease of the works was granted to Owen Williams, son of Thomas Williams, and Pascoe Grenfell in 1803. The partnership ceased in 1825 or 1826 from whence the Grenfell Family continued alone.[79]

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[74] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 99.

[75] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 102

[76] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 110ff.

[77] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 115ff.

[78] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 117ff.

[79] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 121-123.

Between the works at Hafod (see below) and Forest, on the west bank of the River Tawe were a number of other copper works, all in production by the late 1700s. They were the Landore, The Rose and the Birmingham Copper Works. The Birmingham Mining and Copper Company, built their works in the 1790s and had interests in Birmingham, Redruth in Cornwall, as well as Swansea, indicating that the company was also involved in mining copper on its own account in Cornwall. The works continued in production until c.1831 and were acquired by Vivian & Sons.[80]

The Rose Copper Works were owned by a Birmingham Company by 1803. They were the first premises used by the well known firm of Williams, Foster & Company in the 1830s. Sir William Williams, who died in 1870, had extensive mining, smelting and manufacturing interests in Cornwall, Wales and Ireland.[81]

The Landore Works were opened in c. 1800 and were in the possession of the English Copper Company by 1811.[82] They passed into the hands of Henry Bath & Company in about 1825 - 1826, but were bought out by Williams, Foster & Company.

In 1810, Richard Hussey and John Henry Vivian bought a lease near Swansea and erected the Hafod Works on the River Tawe.[83] A new arrangement of furnaces was adopted for the comfort and convenience of the workmen.[84] These works became the pre-eminent smelting works of the area with the Vivian family members, namely John Henry Vivian and H Hussey Vivian, considered the leading men of their day. This was the site of the first though largely unsuccessful experiments to ameliorate the polluting effects of the "Copper Smoke" or sulphurous fumes, undertaken by the eminent Professors Faraday and Phillips in 1812 and Sir Humphrey Davy in 1820 to 1822.[85]

The Nant Ryd Y Vilais Works, again at Landore (or Landwr) had "air furnaces of an exceptional character, neither for Copper nor Iron, and yet for both". They were established about 1814 by Bevans of Morriston for reprocessing the slag of previous

[80] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 127.
[81] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 127-128.
[82] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 129-130
[83] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 125-127.
[84] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 132.
[85] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 136-141.

industry. Although a little copper was produced the large amounts of iron did not lend themselves to welding and so the product of the works was unmarketable and failed.[86]

The Morfa Copper Works were located next to the Hafod Works on a lease from the Duke of Beaufort in 1831. The Copper-Works were built in 1834, near the River Tawe. However the Rolling Mills had already been constructed in 1828 and the Silver-Works completed in 1840, together with a large chimney, on neighbouring land.[87]

One of the more interesting departures for the copper smelting industry of the 1850s onwards was the opening in 1852 of the Port Tennant or Lambert's Copper Works, at the mouth of Swansea Harbour, by Charles Lambert, an extensive mine owner and smelter in Chile. This was a major enterprise by a foreign owner to establish a smelting plant in the World centre of the copper smelting industry.[88]

A mile to the north-east of Swansea, in Cwmbwrlais, the Black Vale Copper Works was established in 1852 to process copper dross and scrap copper and eventually some furnaces for smelting were added to the works.[89]

The Dantygraig Copper Works were opened in 1860, near to the Port Tennant Copper Works. Copper smelting at this site was only a subsidiary of arsenic and sulphur production.[90]

In 1862 the old copper working district on the banks of the River Tawe again saw redevelopment. The Landore Arsenic and Copper Company converted a previous pottery to copper smelting, naming the works the Little Landore Copper Works, to differentiate it from the Landore Works of Williams, Foster & Company. This site was previously occupied by the Llangavelach Works in the 1740s.[91]

86 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 130-131.
87 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 141.
88 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 144.
89 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 145.
90 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 145.
91 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 146.

The Llansamlet Works were established by a Mr Jennings, the former owner of the Dantygraig Works in 1866-1867 on the east side of the River Tawe. They were used for a similar purpose as the Dantygraig works, with copper smelting only as a result of arsenic and sulphur production.[92]

5.1.2. The smelting industry in the environs of Swansea and at other locations in South Wales, 1727 onwards

5.1.2.1. Port Talbot.

"The Governor and Company of Copper Miners in England" or "the English Copper Company" received its Charter in 1691. It had works at Redbrook on the River Wye in Gloucestershire from that date onwards.[93] Messrs. Newton and Cartwright, erected works at Taibach, in the Borough of Aberavon (Port Talbot), with their first lease dating from 1727.[94] The precise date that the English Copper Company took over the works at Taibach is unknown. The Mine Manager, Mr. John Wright, came from Redbrook to manage the works. After his death, management fell to Mr. Philip Jones and then his son, William Jones. Vivian & Sons purchased the works in 1839.[95]

The Cwm-Afan Copper and Metalliferous Works opened up on the east side of the bay at Swansea, near Port Talbot. They were constructed by Vigors & Company in 1837, with a huge chimney which rose up the adjacent hill and towered 1,200 feet above the level of the works themselves. The English Copper Company bought out the owners in 1840 and diversified the works into additional areas of manufacture. [96]

5.1.2.2. Neath.

While the "Battery Works" or "Melting House" of the Mineral and Battery Works Society was located at Neath from the 1680s onwards, there were a number of later

[92] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 1446-147.
[93] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 81.
[94] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 96.
[95] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 103ff.
[96] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 142-144.

Copper Works there, including the Cheadle Copper Works. It commenced in c.1750 but went out of production when sold to Vivian & Sons in 1821.[97]

The Crown Copper Works were also opened in the 1700s at Neath by a Birmingham firm. The works closed in 1866, after passing through a number of leasehold titles.[98]

The Red Jacket Copper Works were erected at the mouth of the River Neath by Messrs Bankart and Sons in 1847.[99]

The Briton Ferry Copper Works was established in 1853 by Bankart & Company, who had opened the nearby Red Jacket Copper Works. .Like Lambert's Copper Works, the works was later owned by the Cape Copper Mining Company, which smelted their own ores from the Cape of Good Hope, S Africa.[100]

5.1.2.3. Carmarthenshire.

The Penclawdd Copper Works, south of the River Loughor on the Gower Peninsula, were commenced by John Vivian, originally from Truro in Cornwall in c. 1800.. He represented the interests of the Associated Miners of Cornwall, who suspected that the true value of their ores was not paid to them by their Welsh smeltermen. Although the works did not answer the purpose of the Associated Miners of Cornwall, John Vivian saw that it was a profitable industry. He sent his second son, John Henry Vivian, to learn the trade from the Mining Schools of Germany. In 1810, Richard Hussey and John Henry Vivian bought a lease near Swansea and erected the Hafod Works on the River Tawe.[101] These works became the pre-eminent smelting works of the area with the Vivian family members, namely John Henry Vivian and H Hussey Vivian, considered the leading men of their day.[102]

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[97] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 124.
[98] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 125.
[99] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 144.
[100] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 145.
[101] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 125-127.
[102] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 136-141.

At the western extremity of the South Wales Coalfields, the Llanelly Copper Works opened at Llanelly in Carmarthenshire in 1805 and were still in production in the 1880s. They were constructed by Messrs Daniel of Cornwall, Savill of London, Guest of Birmingham and Nevill of Swansea.[103]

In 1809 another copper works was opened up on the Loughor River, Gower Peninsula in Carmarthenshire. They were called the Spitty Copper Works, constructed by Morris and Rees. Mr. Rees had been manager at the Penclawdd Copper Works, nearby. Experimentation was made in the extraction of copper by chemical means, but by 1858 the works were leased by the companies of Williams and Vivians, who proceeded to break up the furnace bottoms to render the works inoperable.

The Cambrian Copper Works were opened in Llanelly in 1830, but not proving a success were closed in 1838 - 1840. The site was eventually bought by Messrs. Nevill & Company and used for lead and silver smelting.[104]

The Pembrey Copper Works were erected at Pembrey in Carmarthenshire in 1847 by the eminent firm of Mason & Elkington of Birmingham and London. The site was well known for its 252 feet high stack.

5.1.2.4. Newport.

At the other and eastern extremity of the Welsh Coalfields, the Risca Copper Works opened in 1807 at Risca, near Newport. They were constructed by the Birmingham and Risca Copper Company, but managed from 1811 by the Union Copper Company, Birmingham. The works closed in 1817 because of a depression in the industry and because the company found it cheaper to buy refined copper elsewhere.[105]

[103] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 134.
[104] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 142.
[105] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 134-135.

5.1.3. Copper mining and smelting in Anglesey, North Wales.

New discoveries of copper were made in Wales and Derbyshire in the 1670s.[106] The so-called "Great Discovery" at Parys Mountain in Anglesey was made on 2 March 1768. Legal work undertaken for landowners disputing their boundaries led to the formation of the Parys Mine Company by Thomas Williams in 1774. Smelters were established at Amlwch Port by 1780.

Thomas Williams, born in 1737 on Anglesey, rose rapidly in the copper mining and smelting industry. By 1785 he had gained control of the Mona Copper Mine in Anglesey and at the same time controlled almost all of the sale of Cornish output via a new company called the Cornish Metal Company.

In 1787 there were 31 smelting furnaces at Amlwch Port. These were described in 1797 as "two smelting houses, of which one belongs to each company [Parys and Mona], contain 31 reverberatory furnaces, the chimneys of which are 41 feet high. They are charged every 5 hours with 12 cwt of ore which yields 1/2 cwt of rough copper, containing 50% of the pure metal..... The coals are procured from Liverpool and Swansea." By 1800, Lentin recorded only 20 smelters remaining in the Amlwch area.

After Thomas Williams died in 1802, the quality of ores from the open cut declined. Lord Uxbridge who owned the Mona Copper Mine, formed a new company with the Vivian Family of Swansea in 1811 with a view to extending the mine using the deep mining technology available in Cornwall. James Treweek was sent from Cornwall by Vivian & Company to manage the Mona Mines and the commencement of the deep mining techniques which characterised mineral exploitation in Anglesey until 1883.[107]

5.2. Technological developments, 1580s onwards.

The copper smelting industry in South Wales was strongly associated in its early development with the production of lead. In later years, with the development of a more scientific approach became more closely associated with gold and silver

[106] George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 122.
[107] http:///www.copperkingdom.fsnet.co.uk./history_of_copper mining.htm. http:///www.copperkingdom.fsnet.co.uk./smelting.htm.

production.[108] Because of its secretive beginnings, where technological skills were hidden from view, the furnace technology is normally only briefly described in the literature. There is the mention of conical furnaces at "Middle Bank" Copper Works (1755 onwards, but as late as 1867), the 31 smelters at Amlwch in Anglesey in 1787 and the air furnaces at Nant Ryd Y Vilais Works, Landore in 1814. During the period from the 1580s onwards the standard reverberatory furnace slowly developed, although it lay hidden behind the stone and brick walls of the copper-houses or smelting halls.

One of the developments of the 19th century was the use of a single large chimney to provide draft for a number of furnaces. The traditional smelting halls had numerous chimneys, one for each furnace or small group of furnaces, while the large chimney stacks which are associated with smelter sites in Australia only became noted from the 1830s onwards, notably in 1837 at the Cwm-Afan Copper and Metalliferous Works at Port Talbot and in 1847 at the Pembrey Copper Works in Carmarthenshire.

The Welsh Process of extracting and refining copper was long, costly and tedious when compared with modern technology, but it remained unchallenged until the 1850s. In that year considerable improvements in the smelters were announced at the Great Exhibition, but it was not until Bessemer's invention of the blast furnace, together with the employment of large reverberatory furnaces that output improved.[109]

5.2.1. Reverberatory furnace technology in the United Kingdom.

Because of the secretive nature of the industry in Wales, it is extremely rare that full descriptions of the technology were written down and are still available to us today. The descriptions of the 31 furnaces at Amlwch in Anglesey in 1787 and the 20 remaining in 1800 is therefore extremely valuable as a historical resource.

In 1787 there were 31 smelting furnaces at Amlwch Port. These were described in 1797 as "two smelting houses, of which one belongs to each company [Parys and Mona], contain 31 reverberatory furnaces, the chimneys of which are 41 feet high. They are charged every 5 hours with 12 cwt of ore which yields 1/2 cwt of rough

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108 George Grant-Francis. On the Smelting of Copper in South Wales. Pritchett & Taylor, Printers, London. 1881: 147.

109 B Webster Smith. Six Centuries of Copper. UK Copper Development Association, 1955.

copper, containing 50% of the pure metal..... The coals are procured from Liverpool and Swansea." By 1800, Lentin recorded only 20 smelters remaining in the Amlwch area. He noted that the roasting, calcining, smelting and refining furnaces were almost identical, having chimneys 55 - 60 feet high. The only difference between these and the German equivalents was the openings for the tap hearth and discharge opening. These were replaced on the English calcining and smelting furnaces by large iron trapdoors to allow the ore to be introduced and stirred. The funnel to introduce the ore into the top of the German furnace was replaced by these openings on the English furnace, which were stopped up with brick and sealed with clay.[110]

In 1861, Ure describes the different reverberatory furnaces used in the various stages of smelting, namely the calcining furnace, the melting furnace, the roasting furnace, the refining furnace and the heating or igniting furnace. The calcining furnace served for calcining and the production of matte. It had a vault beneath the hearth into which the ore was raked down after being calcined. Holes in the bottom of the hearth in front of each side opening allowed the calcined ore to feed into the chamber below. The dimensions of the hearth varied from 17 to 19 feet in length, and 14 to 16 feet in width, while the fire-place measured 4 1/2 to 5 feet long by 3 feet wide. At Messrs. Vivian's smelting works, there was a hollow in the fire bridge between the hearth and the grate, which communicated by square holes with the outside, thus allowing oxygen into the furnace during the roasting process. It should be noted that there are four side opening to the furnace, two on each side and no opening in the front of the furnace. Funnels enabled the charging of the furnaces from above, thus clearly indicating that Lentin's description of the furnaces at Anglesey was not the standard English type. Some calcining furnaces possessed two hearths, one above the other.

Ure described melting furnaces as similar to calcining furnaces but usually with a smaller hearth of 11 to 11 1/2 feet long by 7 to 8 feet wide. The fireplace was larger, since it was required to provide a greater heat, namely 3 1/2 to 4 feet long by 3 to 3 1/2 feet wide. The melting furnace has only two openings, apart from the fire-place. One was placed on the side (the tap hole), the other at the front of the furnace (the skimming hole or mouth). The charge was placed into the hearth by a funnel on top of the furnace. Some melting furnaces at Swansea also serve as calcining furnaces, having up to three floors, one above the other. Only the lowest floor is used for smelting, the others for calcining. The floor of the lower hearth is of sand, while those of the upper hearths are of brick.

[110] http:///www.copperkingdom.fsnet.co.uk./smelting.htm.

Ure indicates that the roasting furnace is similar to the calcining furnace. The oxidising atmosphere which was introduced into the furnace by the gap in the fire bridge was patented by Mr. Sheffield, who sold the patent to Messrs. Vivian at Swansea.

The refining furnace had a floor or hearth which sloped to the front so that the copper could be taken out using ladles. The calcining and melting furnaces had floors which sloped to the sides to extract the copper by the tap hole. The roof of the refining furnace is usually higher than in the melting furnace, being from 32 to 36 inches. This is to inhibit the oxidisation of the copper.

Finally Ure described the heating furnace, to reheat the pigs or bars of copper to be laminated or the copper sheets themselves. The furnace was much longer in proportion to its width and a single door ran nearly the whole side of the furnace, as in furnaces for fabrication of sheet iron or brass.[111]

5.2.2. Heap roasting and roasting kilns. in Wales.

The process of heap roasting whereby the ore was heaped up and burnt to remove the sulphur was also used at Anglesey, but allowed all the sulphur to go to waste. By 1787 Matthew Boulton noted that conical brick kilns with brick condensers built into the ground were used to remove the sulphur, after which the sulphur was melted in a cast iron cylinder and poured into moulds.

Bingley in 1798 described an even more elaborate method of removing sulphur from the copper ore. Two parallel walls were erected, some 20, others 40 to 50 yards long, and some 10, others 20 feet wide. The ore was placed in the walled space and the top was covered with stones and sealed with clay and then the ore roasted. Some of the kilns were arched over with brick which was more effective. The sulphur was preserved in other examples by constructing long brick flues with pointed arches, so that the sulphur would condense on the sides of the flues.

Lentin in 1800 also described the ore roasters, which were in use before the conical brick kilns became available. The roaster was similar to those used in Germany and was described as a rectangle, 70 feet long, 20 feet wide and 8 feet high with walls of undressed stone sealed with clay. The internal face was vertical while the external

[111] Ure's Dictionary of Arts, Manufacture and Mines. London. 1861: 822-824.

face sloped out by 4 feet, so that it looked like an oblong pyramid. In the walls were four vents on each side, each 3 feet wide and 3 feet 7 inches high. A single vent was placed at each end. The vents were joined across the length and breadth of the kiln by open brick flues with lids of iron plate, so that the kiln was divided into ten rectangular spaces. The flues were filled with coal and then ore was piled around and over the flues and brought up to a ridge 2 feet wide. Along this ridge a brick flue, 11 inches square internally, was erected, while the ore itself was covered with slate and sealed with clay. At either end of the brick ridge flue, a brick flue led into an adjacent building, measuring 60 feet long, 6 - 8 feet wide internally and 6 feet high which was sealed with plaster to act as a condenser for the sulphur. The building had wooden doors at either end and four vents in the roof.

Lentin goes on to describe the vertical continuous roasting method developed at Anglesey in the 18th century, using conical furnaces. The older calcining furnace, as used at other copper smelting works, as described above, was not continued in Anglesey because of the high cost of bituminous coal, the cost of replacing the iron plates with each firing and the ongoing cost of wages. A conical brick furnace is erected on a base of unfinished stone, 8 feet high and deep enough to take a vaulted passageway 12 feet long and six feet wide. The height of the cone is 27 feet, the lower internal diameter is 16 feet and the upper internal diameter 4 feet. At the base the brick wall is two feet thick, into which are inserted 4 draught holes, equidistant from each other and 2 feet square. The inner edge of these holes is rounded off so that the whole of the base of the furnace can be cleaned out. The whole of the brick cone is strapped with vertical and horizontal iron rails so that it appears as a latticework. The top of the kiln is covered with an iron plate with a 2 feet square opening in it. The ore is thrown into the kiln using this hole and is then covered with an iron plate. The kiln or furnace is attached to a condenser of similar construction to the one used in the older method by a conduit.[112]

5.2.3. Descriptions of smelting and furnace technology from Colonial sources or the United States of America.

The Explorers', Miners' and Assayers' Companion of 1887, published by William Dymock, Sydney, recommended that the ores should be roasted where convenient before being transported to market, so that the weight of the ore is reduced and the

[112] http:///www.rhosybolbach.freeserve.co.uk/calciners.htm.

sulphide ore is partially refined to a "matte" or "regulus".[113] Carne describes this process as having occurred at Copper Hill Copper Mine near Molong between 1847 and 1851.[114]

The Explorers', Miners' and Assayers' Companion described the construction of a flat bottomed reverberatory furnace for this purpose, measuring approximately 16 feet long by 10 feet wide. The other dimensions are as follows:

Length of hearth	10 feet.
Breadth of hearth	7 feet.
Height of the roof above the hearth at the bridge end	1 foot 4 inches.
Height of the roof above the hearth at the chimney end	1 foot.
Breadth of the fireplace	6 feet.
Length of the fireplace	2 feet.[115]

The heat resistant parts of the furnace would be made of "fire bricks, laid on edge; of fire rock, or fire-sand and clay; and the whole structure must be bound with external iron tie-bars". It also described the construction of an expensive set of flues and a chimney taking advantage of the slope available. The illustration of the reverberatory furnace shows the location of air holes (O), two raking holes (R), the charging hopper (H) and the discharge (D), otherwise known at the tap hole. It also shows the asp-pit (A) and the fuel and fire bars (B).[116] The English reverberatory furnace, as described by Lentin in 1800, did not have the hopper or funnel, although this was present on the German furnaces.[117] The illustration shows no vault under the furnace floor, although this is a feature of the furnaces at Cadia (certainly on Furnaces 1, 2 and 5, and possibly 3 and 4), but does clearly illustrate the type of ash pit found at Cadia.

The reverberatory furnace was also considered suitable for smelting both lead and copper, which is not surprising when it is considered that from the beginning the Welsh industry was closely associated with the smelting of both ores.[118]

113 The Explorers', Miners' and Assayers' Companion, William Dymock, Sydney, 1887: 497.
114 J E Carne, *Copper Mining* 1908, p. 138-139.
115 The Explorers', Miners' and Assayers' Companion, William Dymock, Sydney, 1887: 557.
116 The Explorers', Miners' and Assayers' Companion, William Dymock, Sydney, 1887: 497.
117 http:///www.copperkingdom.fsnet.co.uk./smelting.htm.
118 The Explorers', Miners' and Assayers' Companion, William Dymock, Sydney, 1887: 557.

Towards the end of the 19th century, in his *Modern Copper Smelting*, first published in 1895, E D Peters described the evolution of the reverberatory furnace from its 9 feet by 14 feet hearth, with its smelting capacity of 12 tons per 24 hours.[119] He also reveals the purpose of the vault under the furnace floor, which was traditionally to cool down the floor of the furnace and was called a "cooling vault". He questions the advantages of this effect, since it is always difficult to keep the furnace floor hot enough to stop the copper matte from sticking to it. The cooling vault has been filled up in some instances, resulting in a deepening or lowering of the hearth which could be stabilised by leaving a protective layer of matte. It is the tendency of each furnaceman to extract more copper matte from the furnace than his predecessor and this can be achieved by emptying more matte from the bottom of the furnace on each occasion. This exposes the floor of the furnace to the corrosive effect of the next charge of fuel, which will increasingly damage a good furnace floor. Peters advised the placing of a bar across the base of the tap hole so that too much matte could not be drained off, thus protecting the floor of the furnace. Peters recommended that furnaces should be built in future without cooling vaults, but instead be laid on a carefully prepared footing of clay.[120] It may be suspected that the purpose of the vault was also to arrest rising damp, which would have equally damaged the furnace floor.

Peters points to critical factors in the design of the reverberatory furnace, including the height and dimensions of the chimney, the use of dampers, the height of the arch above the furnace bridge and the expansion of space in the furnace itself where the gases have reached their greatest mass. Another factor was the size and depth of the fire bars below the bridge, which was determined by the type of fuel used. For this reason the deep clinker-grates of the Welsh furnaces were abandoned by smelters in the USA, who used a bituminous or semi-bituminous coal. Shallower grates were adopted. The depth of the grate below the fire bridge may also be a critical factor for the furnaces at Cadia, although this is difficult to measure since none of the bridges survives intact. Peters pointed out that the standard depth in the USA was 2 feet below the bridge.[121]

Peters also pointed out that every furnace needed to be tied together with tie-rods and buckstays. The lower tie-rods could be secured by hooking over the edge of the cooling vault, while the upper tie-rods traversed the top of the furnace. The vertical buckstays should be I-beams rather than rails, because of savings in weight.

119 E D Peters. Modern Copper Smelting. 1895:445.
120 E D Peters. Modern Copper Smelting. 1895:448-459.
121 E D Peters. Modern Copper Smelting. 1895:459-460.

Buckstays were also used to support the skewbacks (sloping roof of the furnace) around then entire furnace.[122]

The traditional bottom of a hearth was made of sand smelted in place, but due to the rapid wear of this type of base, new developments were taking place in smelting on brick bottomed furnaces. While none of these is seen at Smelter No. 1 at Cadia, Peters reported that they were in use in South Wales (Burry Port Works of the Cape Copper Company and Elliott's Metal Company's Works (silver smelting).[123]

E D Peters also describes how the ore, fuel, slag and matte are handled in modern works. The ores and fuels should be dumped directly into the hoppers or bins feeding the furnaces, so that materials handling is kept to a minimum. An overhead rail system is desirable, though not always possible. The preferred method of disposing of slag is by granulation using an ample flow of water to granulate the slag as it flows from the furnace. Where water is not available it can be tipped into Nasmyth pots, usually mounted on trucks in pairs and dumped. The older method of sand filled troughs and settling pots appears to have been used at Cadia Smelter No. 1.[124]

E D Peters describes the construction of a standard reverberatory furnace. The foundations are dug 18 inches wider than necessary all round, making allowance for the stack or down-take. A 4 feet depth is sufficient and should be drained, although deeper footings may be required for a stack. Two longitudinal walls are constructed in red brick, leaving a 5 feet gap for the cooling vault under the furnace. The arch is constructed using a lower level of red brick and an upper layer of fire brick. The footings for the front of the furnace, the bridge wall and walls of the ash pit are also constructed in red brick. Tie-rods may be secured by bending their ends into the masonry. They should not be passed under the bed of the furnace, as they will eventually melt. It is safer to bed them lower down, with their ends in the cooling vault, and secured by longitudinal bars and a small number of cross ties.

The footings of the furnace having been built to a foot below the floor, the hearth is now constructed in the shape of an inverted arch, the lowest point being in contact with the apex of the cooling vault arch. The side walls are enclosed in fire brick to support the arch when the right height is reached, the outer walls of the furnace can be constructed in red brick.

[122] E D Peters. Modern Copper Smelting. 1895:460-463
[123] E D Peters. Modern Copper Smelting. 1895:465-467.
[124] E D Peters. Modern Copper Smelting. 1895:465, 471-472.

Two heavy cast iron plates support the hearth at either end, the “conker plate” gives strength to the bridge wall, while the front plate is placed under the front door, with the narrow skimming plate resting upon it. The bridge wall itself is constructed of firebrick with a gap for the “conker plate” and a thinner plate on its posterior side. Air holes may be constructed on either side of the firebox at this point. They can generally be left blocked and only opened when an oxidising atmosphere is required, for example, in the concentration of matte or the making of blister copper. The fire-box is constructed with an inner face of firebrick and an outer skin of red brick.

The arch of the furnace itself is best constructed of “Dinas” brick, which is more durable than fire brick. The roof should pitch down from a position in front of the fire wall to a point near the skimming plate or front of the furnace. The front row of arch bricks, immediately behind the flue opening is called the “vulcatory” and will need frequent renewal due to the intense heat at this point. The flue opening itself is bounded by the “vulcatory”, the front wall of the furnace and the two converging side walls, forming a trapezoidal shape. Its size and dimensions, as well as the size of the flue, are critical for the efficient working of the furnace and will determine the heating capacity of the furnace as well as fuel efficiency. The speed of the draught can be dampened to a minimum level to still enable rapid smelting, by inserting a sand wall at the entrance to the flue, which can be adjusted by removing the metal plates covering the flue at this point.

A row of small holes can be inserted in the arch of the furnace anterior to the fire bridge, to ensure that the gases are combusted in the furnace and not in the flue or chimney where they have a completely deleterious effect.

The arrangement of tie-rods and buckstays is of great importance, with general arrangements shown in plans and drawings. The front plate and “conker plate” should be secured by the buckstays at either end, while the arch of the furnace should be supported by near horizontal skewbacks along both side walls, held in place by the buckstays.

There should be ample space around the furnace, 15 feet on the tapping side, the same distance in front, while a space of 12 feet on the charging-door side is sufficient. The work areas should be paved with brick or other material.

The sand bottom of the furnace is only smelted into place once the stack is completed. It is a slow process where the furnace and cooling vault is dried out by lighting fires in the hearth and ash pit. The sand for the furnace floor is only inserted once the furnace is completely dried and the iron grate constructed in the fire-box.[125]

5.3. Smelting processes.

The processing of smelting copper ores is described in historical texts and included a number of stages.

Lentin in 1800 described the copper smelting processes in use in Anglesey, North Wales.

1. Roasting. The first process was the roasting of the ores, whereby the sulphur would be separated from the ore, either to allow the sulphur to go to waste, as in heap roasting, or by using specially constructed roasting kilns or conical furnaces. These processes were described by Matthew Boulton in 1787, Bingley in 1798, Lentin in 1800 and Faraday in 1819 at the mines in Anglesey in North Wales.

2. Calcining. The second process involved taking the partially roasted ores and placing them in a calcining furnace, to further remove the sulphur content of the ores.

3. Smelting. The third process consisted of the smelting of the ore with fluxes, as appropriate. The ore was frequently smelted with slag derived from previous operations. The smelting process removes any remaining sulphur, melts the metal and slag into a fluid state, so that it may be drawn off at the tap hole into a sand filled frame, where the metal (matte or regulus) and slag solidifies into the shapes cut into the sand.

4. Smelting. Once the product has cooled in the sand frame, it is broken up and the matte or regulus is separated from the slag. The matte is then again smelted in the fourth process. Any slag is skimmed off and the remaining metal is led out through the tap hole into a water container, which causes the metal to separate out into small granules, the process being called granulation. The purpose of the fourth process is again to remove remaining sulphur, while the granulation of the metal provides a greater surface area to remove further sulphur in the next process.

[125] E D Peters. Modern Copper Smelting. 1895:476-481, 483-487.

5. Calcining. The granulated metal is placed in a calcining furnace and heated without melting in this fifth process to remove further sulphur.

6. Smelting. The product is then placed in a smelting furnace in the sixth process. The floor of this furnace slopes to the front and would be described by Ure as a refining furnace. The slag is skimmed off and the metal ladled out into boxes, so that thin sheets of laminated copper are produced, about 1/4 inch thick. The metal is now in the state of a very impure black copper, which cannot be broken. The thin sheets provide a large surface area for the volatilisation of any remaining impurities.

7. Smelting. The cakes of black copper are placed in another similar furnace and slowly brought to a melting temperature. The metal simmers for a number of hours to allow the calcined parts to scorify.[126] The slag is skimmed off and the copper ladled into boxes as before. This produced what was known as "Blister copper".

8. Refining. The final refinement of the copper cakes is again achieved in a refining furnace with the addition of a quantity of lead. The slag is progressively skimmed off to allow the calcination of the copper being scorified. The fluid mass is then sprinkled with coal dust and subjected to the process of poling, whereby green wood branches are forced into the fluid, which causes a violent bubbling, thereby purifying the copper. Further coal dust is thrown onto the fluid copper and bubbling continues. Once this process is complete the copper is either made into cakes, granulated into feather-shot or poured out into small bars or ingots.[127]

In 1847, O Jones of Beaumaris also described the smelting processes at Anglesey. Following on from roasting, he listed the process undertaken:

1. The ores are calcined.
2. The calcined ore is melted.
3. The metallic mixture from process 2 is calcined.
4. The calcined coarse metal is melted.
5. The material from process 4 is calcined.
6. The metal calcined in process 5 is melted.
7. The copper from process 5 is roasted.
8. The coarse or blister copper is refined.

[126] "Scoriae" are waste materials or slags. Scorification (n) or scorify (v) therefore means the removal of these waste materials.
[127] http:///www.copperkingdom.fsnet.co.uk./smelting.htm.

Jones also indicated that the ores needed fluxes for successful smelting and for this purpose ores were obtained from all parts of the World.[128]

The original method, described by Lentin in 1800, had included roasting, calcining, smelting (2 stages), calcining, smelting (2 stages) and refining. The 1847 sequence of alternating calcination and smelting indicates that the copper smelting processes used at Anglesey had changed or were adapted to changed conditions between 1800 and 1847. The most probable reason for the change in the smelting process was a difference in the ores being processed. The open cast mine at Parys Mountain was exhausted by 1800, which led in 1811 to the use of Cornish deep mining techniques. The deeper mining no doubt produced larger quantities of pyritic and sulphide ores and less oxide or carbonate ores. The use of ores from other mines as fluxes tends to confirm the intractability of the Parys Mountain ores by themselves.

The language used by Lentin and Jones also indicates that the chemical processes were not completely understood by the writers. For example, the real purpose of poling was to release the oxygen from the copper.[129]

In 1861, Ure described the smelting processes used in Swansea where he described the predominant ores as cupreous pyrites and "gangue" (iron ore or rock), containing nearly equal parts of sulphide of copper and sulphide of iron.

The processes were described as follows:

1. Calcination of the ore. The ores from various mines are mixed into a consistent mixture for the smelting process. By the calcining process a large proportion of the copper sulphides become copper oxides, exchanging sulphur and arsenic for oxygen.

2. Fusing of the calcined ore. The ore is mixed with slags or other fluxes and smelted. The slag is raked off when the smelt is complete, and a further charge of calcined ore is added and the process repeated. Further charges of calcined ore are added until the liquid matte at the bottom of the furnace reaches the level of the front of the furnace (level of the skimming bar). This normally takes two or three charges of ore. The matte is then drawn off at the tap hole and granulated by the process previously described at Anglesey. The granulated matte contains about 33% copper, the other principal components being iron and sulphur.

[128] http:///www.rhosybolbach.freeserve.co.uk/smelting.htm.

[129] B Webster Smith. Six Centuries of Copper. UK Copper Development Association, 1955.

The purpose of this second process is to make a fusible mass of the ore and other components, so that the ore settles by gravity beneath the slag which can then be skimmed off. This fusibility is achieved by charging the furnace in the second process with slag derived from process 4.

The slag from process 2 is often broken up and any rock containing copper ore is again smelted in a subsidiary process.

Note that Lentin in 1800 does not describe the separation of the matte from the slag, except after the tapping process had been completed. The matte and the slag were then separated mechanically, rather than by gravity in a fluid state.

3. Calcination of coarse metal. The purpose of this process is to oxidise the iron content of the ore, which is now more easily achieved since the ore has been separated from the majority of the earthy substances.

4. Melting of calcined coarse metal. The matte is smelted with slag from process 7 which contains copper oxides. The oxygen and sulphur combine to produce sulphuric acid, leaving a purer form of copper. The slag from this process is used in process 2, while the matte is granulated (named "fine metal" by the smelters) or run into pigs or ingots ("blue metal") with approximately 60% purity.

5. Calcination of fine metal (second matte). This is undertaken in the same way as process 3.

6. Melting calcined fine metal. This process is similar to process 2, which produced the first matte. The black copper produced is run into ingots for roasting. It contains from 70 to 80% pure copper.

In many instances processes 5 and 6 have been omitted and the "blue metal" ingots or pigs go straight to the roasting stage described in process 7.

7. Roasting coarse copper. The purpose of this process is to oxidise the iron remaining in the copper. The temperature of the furnace is gradually increased so that the process is allowed to finish before the copper is melted and poured into ingots and known as blister copper, because of the oxygen that bubbles and escapes from the copper as it solidifies.

The slag from this process is rich in copper oxides and together with the slags from processes 6 and 8 is reused in process 4.

Sometimes the roasting is repeated up to four times, in which case the calcining and smelting of processes 5 and 6 are omitted.

8. Refining or toughening the copper. The pigs of copper are heated to a roasting temperature in a refining furnace to release the last impurities before the temperature was increased to melt the copper. Any final slag was skimmed off before the poling of the copper using branches of green wood. At all times the surface of the copper bath was kept covered with charcoal and stirred with the branches, so as to cause violent bubbling of the copper and the release of any remaining oxides. The product of this process was drawn off and moulded into ingots. In some difficult cases, lead was added to the copper to assist in refining.[130]

The processes described by Ure are therefore similar to those described by Jones in 1847 at Anglesey.

The processes for Smelter No. 1 at Cadia were outlined by the wandering reporter for the *Sydney Mail* on 16 September 1865.

> “The first process to which the ore is submitted is that of calcining, by which the water and some of the earthy particles are removed. The second is smelting the calcined ores, by which a large portion of the siliceous matter is taken out, the remainder forming with the iron into a slag that has been found to be a valuable flux for the richer ores. The third process is the melting of the results of No. 2, which gives a regulus of about 45 per cent., with the best carbonate of oxide ores, containing themselves a per-centage of from 20 to 30 of copper. This brings on the metal to about 60 to 65 per cent., and it then undergoes the fourth process by being charged into the wasting furnace, by which it is brought up to about 80 per cent. By the fifth process it is returned in blocks to the roasting furnace, where it is roasted into copper of about 98 per cent. The sixth and last process is charging the process of No. 5 into the roasting furnace, where it is converted into pure copper of standard quality. In this last instance, the charge is usually about 8 tons, and the process occupiers twenty-four hours. In the calcining

[130] Ure’s Dictionary of Arts, Manufacture and Mines. London. 1861: 824.-827

furnace about 40 to 60- tons a week are roasted and prepared for the subsequent operations, the quantity of course decreasing as the various operations are gone through. The quantity of ore smelted is usually about 200 tons per month, and this gives a monthly yield of about thirty tons of pure copper, being at the rate of from 15 to 16 per cent. The smelting is all done with wood for fuel, and for the above quantity of ore no less than 1200 tons of firewood are consumed."[131]

The processes may be summarised as follows"

1. Calcining.
2. Smelting to provide a matte or regulus of 45% pure copper.
3. Smelting with carbonate of oxide ores to produce a matte of 60 to 65% copper.
4. Wasting furnace, smelting to about 80% purity.
5. Roasting furnace, smelting to about 98% purity.
6. Roasting furnace, smelting to pure or standard copper.

It is possible that processes 2 and 3 were undertaken in the same furnace, so that the ore was taken from the calcining furnace to a smelting furnace, to a wasting furnace and finally to the roasting or refining furnace. The wasting furnace is a term not repeated in the available historical literature, but the process must have included smelting in order to refine the copper from 65 to 80% purity.

The processes used at Cadia are similar to those used in Swansea, South Wales, as described by Ure. They are compared as follows:

1. Calcination of the ore.
2. Fusing of the calcined ore.
3. Calcination of coarse metal. This process appears not to have been undertaken at Cadia.
4. Melting of calcined coarse metal.
5. Calcination of fine metal (second matte). Again not undertaken at Cadia.
6. Melting calcined fine metal. Again not undertaken at Cadia.
7. Roasting coarse copper to produce blister copper.
8. Refining or toughening the copper.

Ure indicated that processes 5 and 6 could be omitted and this is certainly what happened at Cadia, with the ingots produced in process 4 going straight to the roasting

131 *Sydney Mail* , 16 September 1865.

and refining processes 7 and 8. It is also apparent that process 3 seems to have been omitted at Cadia, indicating that by 1865 the more complex smelting processes for pyritic ores were not yet required. They were smelting sulphide, mixed with carbonate ores as a flux. The carbonate ores were located nearer the surface and probably the mining at Cadia had not yet encountered the pyritic ores usually found at greater depths. The pyritic ores would certainly have required initial roasting and calcining and probably the inclusion of process 3.

5.4. Furnaces and smelting at Cadia - adaptations to local conditions.

Research into the background of copper smelting in the United Kingdom and the development of the technology of furnaces and smelting up until the end of the 19th century enables Cadia, and particularly Smelter No. 1 to be placed in context.

Unlike the Welsh smelting houses or halls of an earlier period, the smelting hall at Cadia was connected to a single large chimney stack by a principal and subsidiary flues. This development only appears to have taken place in South Wales in the 1830s and 1840s, so the use of it at Cadia represents the rapid transfer of technological improvements to Australia.

The presence of a conical furnace at Cadia, with 6 fire boxes (Furnace 7) is extremely unusual in the available historical documentation. It is clearly identified as a calcining furnace and was therefore used at the initial stages of the smelting process. The only parallels to this type of furnace are the conical furnaces developed in Anglesey, North Wales for calcining or roasting, although the latter are associated with the condensing of the sulphur and then its melting into a marketable product. While the version of the conical furnace used at Cadia may simply be for calcining or initial roasting, the implication is that attempts were made to condense the sulphur, either for production of sulphur as a marketable product or to lower the level of pollution by the “Copper Smoke”, which was so prevalent at Swansea in South Wales. The earliest experiments in the reduction of the “Copper Smoke” were undertaken in Swansea in 1812 to 1820 - 1822 by Vivian & Company. The difficulty with the condensation of sulphur is that the furnace is not well preserved and there are no traces of the condensing equipment.

The smelting furnaces at Cadia appear to be standard reverberatory furnaces of Welsh design. They were clearly erected by persons of Welsh background, though further research into persons like John P. Christoe would provide useful information in this regard.

The hearth measurement of Furnace 6, being 4 metres (13 feet) long by 2.73 metres (9 feet) wide is representative of the furnaces at Cadia. This is slightly larger than the smelting furnaces described by Ure at Swansea in 1861, but smaller than the calcining furnaces there. It may therefore be assumed that the Cadia reverberatory furnaces were within the usual range for traditional reverberatory furnaces in South Wales. They are also comparable with the furnaces described by Peters in 1878, just before the advances were made in reverberatory technology, which saw their size increase greatly. The dimensions given by Peters for the hearth vary from 14 to 15 feet long by 9 to 9 feet 8 inches in width.

It is difficult to ascertain whether the furnaces at Cadia showed any great adaptation to local conditions. Peters identifies certain features as critical to efficiency, including the height and dimensions of the chimney, the use of dampers, the height of the arch above the furnace bridge and the expansion of space in the furnace itself. Another factor was the size and depth of the fire bars below the bridge, which was determined by the type of fuel used. Also of importance was the flue opening itself. Its size and dimensions, as well as the size of the flue, are critical for the efficient working of the furnace and will determine the heating capacity of the furnace as well as fuel efficiency.

The difficulty faced by the remains at Cadia is that few of these measurements can be taken, because of the total destruction of the furnace superstructures. Only in one instance does the floor or hearth of the furnace survive in Furnace 6.

The smelting processes used at Cadia in 1865 indicate adaptation to local conditions. The process was adapted to the smelting of sulphide ores, mixed with carbonate ores. They differed from the processes used in Swansea and Anglesey at this time, because the latter were designed for the efficient processing of pyritic ores, which are generally found at a greater depth than appears to have been achieved at Cadia by this time. This assumption appears to be contradicted by the available references to the ores mined at Cadia for pyritic ores were clearly mentioned as early as 1859, but may not have been exploited on any great scale until later years.

6. CULTURAL SIGNIFICANCE.

6.1. Cultural significance.

6.1.1. Current assessment criteria.

The importance of the subject site will be assessed in general terms according to its cultural significance. The criteria for assessment of significance have been recently updated by the heritage Office of NSW.

The State Heritage Register and the State Heritage Inventory were established under Part 3A of the Heritage Act (as amended in 1998) for listing of items of environmental heritage.[132] The State Heritage Register list items which are of state heritage significance, while the State Heritage Inventory includes items of local (or regional) heritage significance.[133]

To be assessed for listing on the State Heritage Register (state significance) or State Heritage Inventory (local or regional significance) an item will, in the opinion of the Heritage Council of NSW, meet one or more of the following criteria.[134]

a) an item is important in the course, or pattern, of NSW's cultural or natural history;

b) an item has strong or special association with the life or works of a person, or group of persons, of importance in NSW's cultural or natural history;

c) an item is important in demonstrating aesthetic characteristics and/or a high degree of creative or technical achievement in NSW;

d) an item has strong or special association with a particular community or cultural group in NSW for social, cultural or spiritual reasons;

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132 ***environmental heritage*** means those places, buildings, works, relics, moveable objects, and precincts, of state or local heritage significance (section 4, *Heritage Act, 1977*).

133 ***state heritage significance***, in relation to a place, building, work, relic, moveable object or precinct, means significance to the State in relation to the historical, scientific cultural, social, archaeological, architectural, natural or aesthetic value of the item (section 4A(1), *Heritage Act, 1977*).

134 Guidelines for the application of these criteria have not been prepared by the NSW Heritage Office to date, but reference should be made to the NSW Heritage Manual, which includes the previous wording for these criteria.
Heritage Office and Department of Urban Affairs and Planning. 1996. Heritage Assessments. pp. 4-7.

e) an item has potential to yield information that will contribute to an understanding of NSW's cultural or natural history;
f) an item possesses uncommon, rare or endangered aspects of NSW's cultural or natural history;
g) an item is important in demonstrating the principal characteristics of a class of NSW's
- cultural or natural places; or
- cultural or natural environments.

An item is not to be excluded from the Register or Inventory on the ground that items with similar characteristics have already been listed on the Register or Inventory.

The NSW Heritage Manual provides for three levels of significance, namely local, regional and state. While the new criteria have abandoned the use of the term "regional", nonetheless the use of the term is still considered beneficial to differentiate between items of local and regional significance, even though both categories are only appropriate for listing on the State Heritage Inventory or Local Environment Plan (LEP).

(In criteria a to g, where an item is deemed to be of local significance, the word locality should be substituted for NSW. Where an item is deemed to be of regional significance, the word region should be substituted for NSW).

6.1.2. Previous assessment criteria, 1996.

In 1996 the assessment criteria were standardised by the Heritage Office and Department of Urban Affairs and Planning in the *NSW Heritage Manual*..[135] These previous assessment criteria are summarised below for reference purposes. Some practitioners may still prefer to use the three criteria relating to level of significance, namely local, regional and state, although there is only provision to use the levels local and state under the current guidelines.

Where there is an equivalence between the current and previous guidelines, a letter (a-g) referring to the current criteria is placed against the previous definition.

[135] Heritage Office and Department of Urban Affairs and Planning. 1996. *NSW Heritage Manual*.

Nature of significance.

Historical significance (evolution and association) (criteria a and b). An item having this value is significant because of the importance of its association with, or position in the evolving pattern of our cultural history.

Aesthetic significance (scenic / architectural qualities / creative accomplishment) (criterion c). An item having this value is significant because it demonstrates positive visual or sensory appeal, landmark qualities and/or creative or technical excellence.

Technical / research significance (archaeological, industrial, educational, research potential and aesthetic significance values) (criterion e). Items having this value are significant because of their contribution or positive contribution to an understanding of our cultural history or environment.

Social significance (contemporary community esteem) (criterion d). Items having this value are significant through their social, spiritual or cultural association with a recognisable community.

Degree of significance.

Representativeness (criterion g). Items having this value are significant because they are fine representative examples of an important class of significant items or environments.

Rarity (criterion f). An item having this value is significant because it represents a rare, endangered or unusual aspect of our history or cultural environment.

Level of significance.

Local. Comprises items significant in a local historical or geographical context or to an identifiable contemporary local community.

Regional. Comprises items significant in a regional historical or geographical context or to an identifiable contemporary regional community.

State. Comprises items significant in a state-wide historical or geographical context or to an identifiable contemporary state-wide community.[136]

6.2. Technical / research significance and archaeological significance.

The term 'archaeological significance' may be defined as the extent to which a site may contribute knowledge, not available from other sources, to current themes in historical archaeology and related disciplines.[137] 'Archaeological significance' is included in criterion e of the current criteria for assessment.

In the assessment of archaeological significance, several factors or criteria have to be taken into account. Questions include:

1. Does the site contribute knowledge not available from other sources? In this respect, the preservation of the site, the availability of comparative sites, and the extent of historical documentation should be considered.
2. Does this knowledge contribute meaningfully to current research themes in historical archaeology and related disciplines? The level of this contribution may be assessed on the same basis as other aspects of cultural significance, for example, locality, region or state.

It is clear that the determination of archaeological significance is closely related and, in fact, dependent upon the development of current research themes in historical archaeology. Research themes will be discussed in this study, thereby giving the

[136] The above assessment criteria were extracted verbatim from Heritage Office and Department of Urban Affairs and Planning. 1996. Heritage Assessments. pp. 4-7.
[137] This definition is based upon the following references; A. Bickford, & S. Sullivan, 'Assessing the research significance of historic sites', in S. Sullivan, & S. Bowdler, *Site survey and significance assessment in Australian archaeology*, Dept. of Prehistory, Research School of Pacific Studies, ANU, Canberra, 1984, pp. 19-26.; S. Sullivan, & S. Bowdler, *Site survey and significance assessment in Australian archaeology*, Dept. of Prehistory, Research School of Pacific Studies, ANU, Canberra, 1984, passim.

historical archaeologist a framework or starting point from which future research and site assessment may proceed.

6.3. Social significance and educational or public significance.

It is also necessary to clarify the significance of a site in terms of its ability to 'demonstrate a way of life, taste, custom, process or function of particular interest.'[138] This factor was given greater emphasis by J. S. Kerr in the assessment of cultural significance in the second edition of his book, entitled *The Conservation Plan*.[139] This may be described as its educational or 'public significance', and may be recognised as social significance under the current guidelines.[140]

The cultural landscape, the patchwork of human development, may possess this social significance, because of its educational value. The evidence provided by the physical remains complements historical documentation, but is often the only means whereby the ordinary member of the public may appreciate his or her surroundings.

Where an artifact, an archaeological feature or site only survives underground, it takes archaeological excavation to reveal its social or educational importance, as well as recover its archaeological significance. Providing the relics or sites are conserved in some way, then the social significance of the archaeological remains is recognised or is able to be recovered at some future date.

6.4. The significance of the cultural landscape.

Human settlement imposes on the landscape a distinctive pattern or patchwork of houses and other buildings, streets and roads, parks and reserves, communications and industry. This physical evidence enables an understanding of the landscape in terms

[138] J. S. Kerr, *The Conservation Plan. A guide to the preparation of conservation plans for places of European cultural significance*, first edition, National Trust of Australia (N.S.W. Branch), Sydney, 1982, p. 4.
[139] J. S. Kerr, *The Conservation Plan. A guide to the preparation of conservation plans for places of European cultural significance*, second edition, National Trust of Australia (N.S.W. Branch), Sydney, 1985.
[140] M. Pearson, 'Assessing the significance of historical archaeological resources', in S. Sullivan, & S. Bowdler, *Site survey and significance assessment in Australian archaeology*, Dept. of Prehistory, Research School of Pacific Studies, ANU, Canberra, 1984, p. 32.

of land use, sequence and nature of settlement and occupation. It complements the information that is available from historical research.

Thus all items in an inventory of sites possess **historical significance (criterion a)** as defined under current guidelines, although each will contribute in varying degree. The minimum degree of historical importance will be representative and the minimum level will be local. This means that at least an item will be important to the locality in terms of being representative of the nature of settlement. In many cases items may demonstrate a former use or continuity of use, thereby becoming important items in the historical landscape.

In as much as each item in an inventory contributes to an understanding of the human occupation and evolution of the rural or urban landscape, so too will it possess an educational role for the wider community. This is defined as **social significance (criterion d)** under current guidelines. Social significance may also extend to other values held by the community and placed upon the landscape or items within it, be they social, cultural, religious, spiritual, aesthetic or educational values.

6.5. The heritage significance of the subject site.

The heritage significance of the subject site will be discussed under the headings of the assessment criteria:

a) an item is important in the course, or pattern, of NSW's cultural or natural history;
The site of Smelter No. 1 at Cadia is associated with the pioneering or initial development stage of copper mining in New South Wales. While the copper resources of South Australia were exploited from 1844 onwards, the first copper mines in New South Wales date from 1845. Cadia was the first mine to have a relatively efficient and complete range of copper smelting furnaces in New South Wales. The earlier sites had defective smelting furnaces, as described by Scutchbury or Carne. Only the larger and more economic mines possessed smelters.

b) an item has strong or special association with the life or works of a person, or group of persons, of importance in NSW's cultural or natural history;
The smelting of copper at Cadia has strong associations with both Cornish mining technology and Welsh smelting technology and the immigration of the Welsh and Cornish into New South Wales. John P. Christoe, a skilled metallurgist, was in charge

of the smelting of copper at Cadia. He is known to have set up other smelting works in the region before being engaged by the Scottish Australian Mining Company in 1861 to build the smelter at Cadia. The Scottish Australian Mining Company had also been responsible for the development of the Good Hope Mine at Yass in 1848-1849, and were to continue to have an ongoing involvement in copper mining in New South Wales.

c) an item is important in demonstrating aesthetic characteristics and/or a high degree of creative or technical achievement in NSW;
The site of Smelter No. 1 at Cadia has revealed evidence relating to traditional Welsh smelting technologies, the development of these technologies to suit Australian conditions and the use of traditional building techniques in industrial construction.

The smelting furnaces at Cadia appear to be standard reverberatory furnaces of Welsh design. Unlike the Welsh smelting houses or halls of an earlier period, the smelting hall at Cadia was connected to a single large chimney stack by a principal and subsidiary flues. This development only appears to have taken place in South Wales in the 1830s and 1840s, so the use of it at Cadia represents the rapid transfer of technological improvements to Australia.

The presence of a conical furnace at Cadia, with 6 fire boxes (Furnace 7) is extremely unusual in the available historical documentation. It is clearly identified as a calcining furnace and was therefore used at the initial stages of the smelting process. The only parallels to this type of furnace are the conical furnaces developed in Anglesey, North Wales for calcining or roasting, although the latter are associated with the condensing of the sulphur and then its melting into a marketable product.

The smelting processes used at Cadia in 1865 indicate adaptation to local conditions, suitable for the smelting of sulphide ores, mixed with carbonate ores. They differed from the processes used in Swansea and Anglesey at this time, because the latter were designed for the efficient processing of pyritic ores.

d) an item has strong or special association with a particular community or cultural group in NSW for social, cultural or spiritual reasons;
The locations of Cornish and Welsh settlement and workplace in New South Wales have a strong association for the descendants of these communities, especially for community groups related to Cornish identity and history.

e) an item has potential to yield information that will contribute to an understanding of NSW's cultural or natural history;

The site of Smelter No. 1 has revealed aspects of traditional technology, particularly Cornish and Welsh mining technologies and their adaptation to local Australian conditions.

The archaeological investigation has answered some of the key research questions relating to the site of Smelter No. 1, including:

1. Standard aspects of the layout and construction of traditional Welsh reverberatory furnaces and smelting works.
2. Variation in the layout and construction of the smelting works, indicating adaptation to the local conditions found in Australia or New South Wales.
3. The efficiency of the smelting works as a reflection on the professional qualifications and experience of the smelter manager or the work practices of the mining company.
4. Working conditions for those employed at the smelting works.
5. Levels of environmental and workplace pollution.
6. The design and construction of the smelting works as evidence of ethnic groups at Australian mining sites.

f) an item possesses uncommon, rare or endangered aspects of NSW's cultural or natural history;

Smelting works were only associated with the major copper mining sites in New South Wales. Less than 37 mine sites out of a total of eighty copper mines listed by Carne before 1908 possessed smelters. Cadia was the first mine to have a relatively efficient and complete range of copper smelting furnaces in New South Wales. The earlier sites had defective smelting furnaces, as described by Scutchbury or Carne.

g) an item is important in demonstrating the principal characteristics of a class of NSW's

- cultural or natural places; or

- cultural or natural environments.

Welsh technology dominated the Australian copper smelting industry, while Cornish technology dominated copper mining throughout the 19th century in New South Wales. The Cadia Smelter No. 1 clearly shows how Welsh smelting technology was adapted to local conditions and demonstrates a particular stage in the development of reverberatory furnace technology before the improvements and the developments of the 1870s and 1880s onwards. It is representative in indicating a particular stage of development, but rare in all other respects, with the closest known comparative examples located in South Australia.

6.6. Summary of Statement of significance.

The site of Smelter No. 1 at Cadia is associated with the pioneering or initial development stage of copper mining in New South Wales. Cadia was the first mine to have a relatively efficient and complete range of copper smelting furnaces in New South Wales. The earlier sites had defective smelting furnaces, as described by Scutchbury or Carne. Only the larger and more economic mines possessed smelters. Less than 37 mine sites out of a total of 80 copper mines listed by Carne before 1908 possessed smelters.

The smelting of copper at Cadia has strong associations with both Cornish mining technology and Welsh smelting technology and the immigration of the Welsh and Cornish into New South Wales. The locations of Cornish and Welsh settlement and workplace in New South Wales have a strong association for the descendants of these communities The Scottish Australian Mining Company was to have an ongoing involvement in copper mining in New South Wales.

The site of Smelter No. 1 at Cadia has revealed evidence relating to traditional Welsh smelting technologies, the development of these technologies to suit Australian conditions and the use of traditional building techniques in industrial construction. The smelting furnaces at Cadia are standard reverberatory furnaces of Welsh design, but unlike the Welsh smelting houses or halls of an earlier period, the smelting hall at Cadia was connected to a single large chimney stack by a principal and subsidiary flues. This development only appears to have taken place in South Wales in the 1830s and 1840s, so the use of it at Cadia represents the rapid transfer of technological improvements to Australia.

The presence of a conical furnace at Cadia, with 6 fire boxes (Furnace 7) is extremely unusual in the available historical documentation. It is clearly identified as a calcining furnace and was therefore used at the initial stages of the smelting process. The only parallels to this type of furnace are the conical furnaces developed in Anglesey, North Wales for calcining or roasting, although the latter are associated with the condensing of the sulphur and then its melting into a marketable product.

The smelting processes used at Cadia in 1865 indicate adaptation to local conditions, suitable for the smelting of sulphide ores, mixed with carbonate ores. They differed from the processes used in Swansea and Anglesey at this time, because the latter were designed for the efficient processing of pyritic ores.

The site of Smelter No. 1 at Cadia is therefore of state significance. The closest parallels to this site are in South Australia, Swansea in South Wales and in Anglesey, North Wales. Cadia was the first mine to have a relatively efficient and complete range of copper smelting furnaces in New South Wales. The site possessed typical Welsh reverberatory furnaces, while the smelting process was adapted to local conditions. It also possessed a very rare example of a conical furnace for calcining. Smelter No. 1 represents the final stage of development for the standard reverberatory furnace before improvements led to the construction of much larger furnaces during the 1870s and 1880s onwards.

APPENDIX 1. SITE RECORDS.

1. Archaeological site. Primary records.

1. Archaeological features and structures.	Subject to archaeological excavation.
2. Artifact collection.	Catalogued.

1.1. Conservation treatment.

All artifacts have been cleaned, bagged, and packed into archive boxes, except where discarded as having no further research or other value. Oversize items have been stored without packaging. No laboratory conservation was required.

The artifacts were divided into the following categories:

Artifact categories.	**Status.**
1. Aboriginal artifacts.	no artifacts.
2. Bone unworked.	catalogued.
3. Building materials.	no artifacts.
4. Ceramics.	catalogued.
5. Glass.	catalogued.
6. Kaolin	catalogued.
7. Metals.	catalogued.
8.1. Miscellaneous-coins.	no artifacts.
8.2. Miscellaneous-other.	catalogued.
9. Organics.	catalogued.
10. Samples.	no artifacts.
11. Shell unworked.	no artifacts.
12. Stone.	no artifacts.
13. Synthetics.	no artifacts.

2. Secondary and tertiary records.

Secondary site records.	Documentary.	Context catalogue or index.
	Photographic.	Colour negatives and prints.
	Graphic.	Site plans.
Secondary artifact records.	Documentary.	Artifact catalogues
Other secondary records.	None	
Tertiary site records.		Report as presented to client.

3. Permanent archive for all excavation records.

The artifact collection is held by Cadia Holdings Pty Limited.

APPENDIX 2. CONTEXT CATALOGUE.

001	Soil Type 1 - Humic A1 horizon topsoil
002	Soil Type 2 - Inorganic A2 horizon topsoil
003	Soil Type 3 - B horizon clay
004	Soil Type 4 - Erosion deposits
005	Soil Type 5 - Heat affected soils
006	Soil Type 6 - Industrial waste and sludge
011	Unstratified metal objects
012	Unstratified metal objects from vicinity of Furnace 1
013	Artefacts from rubble within Furnace 1
014	Unstratified metal objects from vicinity of Furnace 2
015	Unstratified metal objects from vicinity of Furnace 3
016	Unstratified metal objects from vicinity of Furnace 4
017	Pipe stems on brick pavement north of Furnace 4
018	Unstratified metal objects from vicinity of Furnace 5
019	Artefacts from rubble fill within Furnace 6 firebox
020	Artefacts from vicinity of Furnace 7
021	Artefacts from general vicinity of Structure 6
022	Artefacts from Structure 6, north room floor
023	Artefacts from Structure 6 south room brick structure
024	Unstratified metal objects from clean of box drain Structure 1.02
025	Unstratified metal objects from clean around side flue Structure 4.04
026	Artefacts from cinder layer within side flue Structure 4.04
027	Artefacts from rubble within side flue Structure 4.05
028	Structure 7
029	Structure 7, charcoal deposit at north end
030	Structure 7, channel along south side
031	Pit / Posthole near Structure 7
032	Structure 6
033	Cut or erosion channel? around south-east corner of Structure 6 and apparently cut by its wall plate slot, mixed fill with brick and stone, may run into 034
034	Cut, sub rectangular with dark brown (ferrous?) outline, 96 x 100 cms
035	Cut or erosion channel? appeared to cut 033, mixed fill with brick and stone, sealed by Smelter Hall redeposited clay
036	Cut, running downslope apparently out of 034, width 50 cms
037	Posthole, sub circular diam. 45-50 cms, cuts 036
038	Posthole, sub rectangular 30 x 34 cms, post-pipe 11 x 12 cms
039	Posthole, sub rectangular 46 x 47 cms, brick in packing
040	Posthole, sub circular 34 x 39 cms
041	Pit / Posthole, sub rectangular 37 x 50 cms, mixed fill
042	Structure 9
043	Structure 8
045	Structure 4.02, brick box drain
046	Cut, part of Structure 7?
047	Structure 1.02, brick and stone box drain
048	Structure 1, Smelter Hall postholes
048	Furnace 1
050	Structure 4.03, side flue for Furnace 1
051	Cobblestone pavements in Smelter Hall
052	Structure 4.01, stone wall

053	Structure 4.01, pit, contains 052
054	Structure 4, main flue
056	Structure 1.01, stone wall
057	Pit / Posthole, appeared to cut drain 047
058	Furnace 2
059	Brick pavements in Smelter Hall
060	Layer / Lenses, hard slag gravel accumulations on 059
061	Structure 4.04, side flue for Furnace 2
062	Posthole, sub square 65 x 65 cms, mixed fill
063	Posthole, rectangular 59 x 110 cms, mixed fill
064	Cut, through 061 side flue
065	Brick feature (steps?) adjacent to Structure 4.05
066	Furnace 3
067	Furnace 4
068	Structure 4.05, side flue for Furnace 3
069	Cut, through 068 side flue
071	Cut, rectangular 94 x 176 cms, rubble fill, cut 048 posthole and may replace it (post-pipe 25 cms diameter, signs of burning)
073	Structure 4.06, side flue for Furnace 4
074	Cut? Gap through 059 north of Furnace 4, width 16.5 cms (6 1/2 ins), depth 4 cms
075	Brick feature, short line laid on edge between Furnace 4 and stone paving adjacent to Furnace 3, rectangular frogs
076	Cut, two iron bars (buckstays?) laid into redeposited clay between Furnaces 4 and 5, width 39 cms, bars 8.9 x 10.2 cms (3 1/21 x 4 ins)
077	Furnace 5
078	Cut, rectangular 30 x 40 cms, brick rubble in fill
079	Cut, irregular 100 x 105 cms, brick rubble in fill
080	Cut / depression, circular, 100 x 180 cms, mixed fill, probably = 048 Smelter Hall posthole
081	Cut, sub circular 60 x 90 cms, mixed fill
082	Brick pavement south of Furnace 6
083	Structure 4.08, side flue for Furnace 6
084	Structure 2 postholes around Furnace 6
085	Cut and slag deposit
086	Structure 2, stone and slag wall
087	Brick pavement east of Furnace 6
088	Furnace 8
089	Drain cut? linear feature running downslope from north-west corner of Furnace 6 firebox, width 70 cms
090	Ponds?
091	Structure 4.07, side flue for Furnace 5
092	Brick footing, cut through 091 side flue
093	Cut / erosion channel? feature running downslope from Furnace 7
094	Structure 3 Furnace 7
095	Structure 5, stone retaining wall
096	Structure 5.01, stone and slag footings
097	Smelter Hall platform, clay levelling fill

APPENDIX 3. ARTIFACT ANALYSIS.

Unstratified Metal Objects (Context 011).

The following artifacts were located during machine excavation, mostly in overburden. Excepting a fragment of sheet lead, all are wrought and cast iron and most were severely affected by rust and encrustation. Some can be associated with furnace construction, including fire bars, buckstays, tie-rods and cross-rods. The cross-rod is a form of tie-rod with its end bent over to hold against the inner wall. Several objects are probably the iron fittings for construction in timber. Identifiable tools comprise the heads of paddles and rabbles made of plate iron. The flat paddle with extended tang for handle attachment was used for spreading the material used to make the hearth floor and for spreading a charge of ore evenly around the hearth (Peters, 1895, 470-88). The rabble used for levelling the floor material and for skimming slag was hoe-like having a rectangular head with small lug for handle attachment.

The remainder of the ironwork mostly comprised bars, rods and plates of various shapes and sizes. Given that these items could have served in a number of capacities they cannot be identified with any certainty. Some shorter rods are probably tools, such as those with wedge ends (possible gads or crow bars). A number with pointed ends are possibly pegs or spikes attached to timber superstructures. Some longer rods may be paddle and rabble handles. Various other rods, bars and pieces of plate iron probably represent furnace elements such as saddle bars, lintels and door parts. The standard rods with a 1 inch square section could be parts of tie-rods or bars for fire-boxes.

Smelter Hall (Structure 1).

Plate A3.1.

Location	**Photo position**	**Description**
Area of Furnace 1	Left	Bar
	Rear	Furnace cross-rods, circular rod
	Centre front	Brace?
	Centre	Rabbles and lengths of plate iron
	Right	Saddle bar?

Plate A3.2.

Location	Photo position	Description
Area of Furnace 2 (south)	Front	Peg
	Centre left	Rods
	Centre front	Plate iron (door fixture?)
	Centre rear	Peg
	Right	Furnace cross-rod
	Rear	Fire bar?

Plate A3.3.

Location	Photo position	Description
Area of Furnace 2 (north)	Front left	Plate, circular rod
	Front right	Rod handle
	Centre	Rod (1 inch square)
	Rear	Fire bar?

Plate A3.4.

Location	Photo position	Description
Furnace 2 Firebox	Front left	Three paddles, rabble?
	Front right	Two rabbles
	Remainder	Plates, bars and rods

Plate A3.5.

Location	Photo position	Description
Area of Furnace 3	Front left & centre	Peg, chisel?, peg?,
	Front centre	Rods
	Front right	Rabble, rod (1 inch square)
	Centre	Strap?, peg?, plate iron, cross-tie
	Rear	Frame?

Plate A3.6.

Location	Photo position	Description
Area of Furnace 4	Front left	Bar
	Front right	Wedge-point spike, tie-rod
	Centre	Rod (circular & 1 inch square), rabble, door handle?
	Rear	Arch bars, rod (1 inch square)

Plate A3.7.

Location	**Photo position**	**Description**
Furnace 4 Firebox	Front	Four rabbles
	Centre	Various rods, bars
	Rear	Tie-rods

Plate A3.8.

Location	**Photo position**	**Description**
Furnace 4 Firebox	Front right	Rabble?
	Front	Rods, bars
	Centre left	Rods, bars
	Centre right	Rods, brace?
	Rear	Heavy bar with holes for insertion of adjacent points. The heavy, hooked bar centre right may relate.

Plate A3.9.

Location	**Photo position**	**Description**
Area of Furnace 5 (south)	Front	Bar, rabbles, bar, brace?
	Centre & rear left	Tie-rods
	Rear right	Bars

Plate A3.10.

Location	**Photo position**	**Description**
Area of Furnace 5 (south)	Left	Tie-rods
	Right	Bar fragments, possibly including rabbles

Plate A3.11.

Location	**Photo position**	**Description**
Area of Furnace 5 (south)		Various bars and rods, including two arch bars centre right. Note the two bars with concave ends which may respond to bars with convex ends (see Plate A3.6 Furnace 4 area, front left).

Plate A3.12.

Location	**Photo position**	**Description**
Area of Furnace 5 (south)	Front	Bar
	Centre	Rabble?, timber brace?, bar, bracket for timbers?
	Rear & right	Tram rail

Plate A3.13.

Location	Photo position	Description
Area of Furnace 5 (north) & Main Flue	Front	Fire bars?
	Rear right	Two arch bars
	Remainder	Various rods and bars

Plate A3.14.

Location	Photo position	Description
Area of Furnace 5 (north) & Main Flue	Front & centre	Various bars, rod & sheet iron
	Rear right	End brackets?

Plate A3.15.

Location	Photo position	Description
Area of Furnace 5 (north) & Side Flue S4.07		Two rectangular objects with open top and bottom, very solid with thickened rim. Ingot moulds?

Plate A3.16.

Location	Photo position	Description
Area of Furnace 5 (north) & Side Flue S4.07		Heavy bar (lintel?)

Plate A3.17.

Location	Photo position	Description
Area of Furnace 5 (north) & Side Flue S4.07		Heavy bar (buckstay?)

Plate A3.18.

Location	Photo position	Description
Area of Furnace 5 (north) & Side Flue S4.07		Heavy plate

Vicinity of Furnace 6 (Structure 2)

Plate A3.19.

Location	Photo position	Description
Area of Furnace 6	Front left	Two rabbles
	Centre left	Fragment of sheet with attachments
	Remainder	Various rods and bars, including fragment of tie-rod

Plate A3.20.

Location	Photo position	Description
Area of Furnace 6	Front left	Rabble?
	Front right & centre	Rods
	Rear	Wheelbarrow frame

Vicinity of Furnace 7 (Structure 3)

Plate A3.21.

Location	Photo position	Description
Area of Furnace 7		Various rods, bars and sheet iron

Vicinity of Main Flue (Structure 4)

Plate A3.22.

Location	Photo position	Description
Area of Main Flue	Front left	Rabbles
	Front right	Tool head?
	Remainder	Various rods, bars and sheet iron

Plate A3.23.

Location	Photo position	Description
Rubble fill of Side Flue S4.08		Ladles

Vicinity of Structure 6

Plate A3.24.

Location	**Photo position**	**Description**
Area of Structure 6 (general)	Front left	Rod, cut-down shovel head as a rabble?, wall hook?
	Front right	Two paddles, that to right found on the floor of the south room of Structure 6.
	Remainder	Various rods and bars

Plate A3.25.

Location	**Photo position**	**Description**
Area of Structure 6 (north)	Front left	Sheet lead
	Front right & centre	Rods with circular profile and one flanged end, of unequal length (large structural pins?)
	Rear	Cross-rods

Plate A3.26.

Location	**Photo position**	**Description**
Area of Structure 6 (south)	Front	Bar with rivets
	Centre & rear	Cross-rods & tie-rod

Other artifact categories.

The remaining artifact catalogues are held by Edward Higginbotham & Associates Pty Limited and are available for research purposes on request.