Abstract

This thesis is an archaeological study of the stamp mill, often referred to as a ‘stamper battery,’ that is one of the iconic features of New Zealand’s historic goldfields. After the Otago gold rushes started in earnest in 1861 thousands of men flocked to the alluvial diggings, and they were soon searching for the quartz reefs that they were sure were the source of the river and stream gold. Hard-rock mining started in 1862 in Otago and Coromandel, and machines were erected to crush the rock and release the gold that it (hopefully) contained. These machines were stamp mills, a mechanically simple hammer mill that raised and dropped heavy weights onto the quartz in order to reduce it to the consistency of sand. The first few mills were improvised locally from materials at hand, and these were soon followed by a number of ‘engineered’ stamp mills imported from foundries in Melbourne. A local manufacturing industry quickly grew up, and other mills were imported from Britain and America. Today many examples of these mills survive in the old goldfields in varying states of preservation. They constitute archaeological evidence of two important aspects of the goldfields: technology, and a place of work.

Much Industrial Archaeology has traditionally focussed on technological details, and this is the starting point for this research. Contemporary industry literature is used to describe and understand the engineering of the stamp mill, and this understanding is then applied to the archaeological record. The results of a wide-scale survey that covered sites from Fiordland in the south to the Coromandel in the north are considered in terms of technological adoption, adaption and innovation in order to determine how and why gold milling technology came to New Zealand. The results indicate that the majority of the technology was imported, with Australia acting as a source of conventional technology, and Britain and America as sources of more innovative designs. However, far from being completely technologically dependent on these places, it is argued that New Zealand was a technological participant in the international mining industry. There is ample archaeological evidence for local agency in New Zealand, whereby technology was chosen and adapted to suit local requirements, with some local designs then being re-exported. New Zealand was admittedly never more than small player in this international field, but it was nevertheless an active one.

The thesis then turns to the second issue: the stamp mill as a workplace. Since the 1970s commentators have pointed out that Industrial Archaeology should take note of social issues in the industrial world, but much subsequent work has been criticised because of its focus on technology and structures. By taking the same engineering analysis of the archaeological evidence of the New Zealand stamp mills as used in the discussion of technology, the mill as a place where people worked is considered. Evidence of wear, repair, modification and pragmatic adaption is discussed to identify the work that was actually carried out by the mill workers, and detailed volumetric analysis of various mill parts is used to quantify some of the tasks in relation to contemporary records of workmen’s abilities. Finally, the workplace environment is also considered, including hazards such as noise, dust and poisons. The results of this, unsurprisingly, find that the battery house was by modern standards a very dangerous place. However, it is also observed that in a world without social welfare, the battery house represented employment and income that was vital for the working man and his family.

In conclusion, the stamp mill is part of an archaeological landscape that has both international links and individual social meaning. Modern New Zealand society evolved in melting pot of the nineteenth century, and the gold mining industry played an important role in that development. The combination of evidence of international influence and local agency in mining technology, and the role and experiences of the mill workers, provides a small insight into the emergence of the complex modern world.
Acknowledgements

A very large number of people have assisted with and contributed to this research in many different ways. First of all I would like to thank my Father and late Mother for their encouragement and for introducing me to archaeology as a small child. And special thanks are also due to Jitlada Innanchai (Aew) for her patience and assistance during the two month field survey that this thesis is primarily based upon. I would like to thank my supervisor Ian Smith for his advice and support throughout. I would also especially like to remember the late Les Wright of the West Coast, who died tragically as this research was being completed. His knowledge of mining heritage on the coast was second to none, and our correspondence was invaluable. No one knows how many books will now never be written. He kindly gave me permission to use a number of images.

Numerous members of staff of the Department of Conservation deserve special mention, as they are at the forefront of managing and preserving most of the surviving goldfields heritage in New Zealand. Rachael Egerton in Southland, Jackie Breen and Jim Staton on the West Coast, Marion Sutton and Shar Briden in Otago, Steve Bagley in Nelson and Neville Ritchie in the Waikato have all helped enormously with this research. In addition to these people, there are numerous individuals actively involved with preserving and managing goldfields heritage sites, who not only assisted with my research, but are also ensuring that many of these sites will survive for future generations. For this often arduous work I must thank Ashley Franklyn (Coromandel Government Battery), Kelvin Hynes (Coromandel School of Mines), John Isdale (Thames School of Mines), Paul Thomas (Reefton School of Mines), Val & Dean Currie (Mitchell’s Gully Goldmine). The Historic Places Trust also takes an active role in preserving goldfields heritage, in particular Matt Schmidt and Heather Bauchop.

Many people shared their personal experiences and knowledge of the goldfields with me, which led me to a number of sites and unravelled more than a few conundrums. A simple list of names seems to show scant gratitude, but I am very grateful to Ralph Allen, Euan Warburton, Jill Hamel, David Still, Brenda & Eric Sewell, Dave Wilton, Paul Crump, Bill Watts, Nelson Valient (Hauraki Prospectors’ Association), John Barry, Glenn Mayclair, John Tyler, Bill Cowan, Roger Hodgkinson, Ian Fraser (Findlay Park), Alasdair Mawdsley (Mighty River Power), Robbie Jones (Mighty River Power), Geoff Hansen (Mighty River Power), Thomas Finnie, Graeme Richardson, Jamie Obern (Tech Dive NZ).

Also invaluable are the many friends and colleagues who have helped with fieldwork, provided sounding boards for ideas, discussed goldfields history and archaeological theory, and provided logistical and moral support. I am grateful to Brendon Bland, Alastair Druett, Cathleen Hauman, Mary O’Keefe, Kevin Jones, Andy Brown, Matt Carter, Heather Sadler, James Robinson, Jessie Garland, Phil Latham, Peter Mitchell, Dimitri Anson, Chris Jacomb, Richard Walter, Charles Parkinson, Lorena Sciusco Hayden Cavte, Sheryl McPherson, Cathrine Waite, Marj Blair, Naomi Woods, Tristan Russell, and Nicola Molloy.

A number of institutions (and their staff) have also been essential to this research. The staff in the past at the Otago University Library who acted to keep at least some of the old Otago School of Mines library collection in permanent storage have saved one of the most valuable research tools for goldfields archaeology in the country. The Lakes District Museum and Hocken Library both allowed me to use images from their collections, and the Auckland Public Libraries online heritage images database is a wonderful resource.

Any attempt to comprehensively list everyone who has helped will inevitably fail, and any omissions are inadvertent, for which I apologise.
Table of Contents

Table of Contents ................................................................. v
List of Figures ....................................................................... xiii
List of Tables ................................................................. xxviii

Chapter 1 ................................................................................. 1
Introduction ........................................................................... 1

Chapter 2 ................................................................................. 7
Industrial Archaeology, Theoretical Approaches, Literature Review ................................................................... 7
Industrial Revolution to Industrial Archaeology ........................................................................... 7
Industrial Archaeology ................................................................... 9
Industrial Archaeology in New Zealand ........................................................................ 14

Building a Theoretical Model ......................................................... 16
Technology ........................................................................ 16
Macro- and Micro-Innovation ......................................................... 17
Dependency Theory vs. Technological Sovereignty ........................................................................ 17
Testing the Theories Archaeologically ........................................................................ 18

The Archaeology of the Machine ........................................................................ 19

Literature Review ........................................................................ 20
Contemporary Narrative Literature .................................................. 20
Contemporary Technical Literature ................................................................. 21
Modern Historical & Archaeological Literature ........................................................................ 22

Chapter 3 ................................................................................. 25
Background History & Technology: The development and theory of the stamp mill ........................................... 25

Introduction ........................................................................... 25
Basic Concepts ........................................................................ 25
Gold Mining ........................................................................... 26
Beneficiation and Ore Processing ..................................................... 28
Gold Saving ........................................................................... 29

Stamp Mill Theory of Operation ......................................................... 29
Power Requirements ................................................................... 30
Ore Feed into the Mortar Box ................................................................. 92
Mortar Box Internal Design..................................................................... 93
Inside Amalgamation............................................................................... 94
Inside Linings ....................................................................................... 95
Outlets: Single & Multiple Discharge, Screens ........................................ 95
Single Discharge Boxes ........................................................................ 96
Multiple Discharge Boxes .................................................................... 96
Screen Mountings ................................................................................ 98
Screens ................................................................................................ 99
Screen Material ................................................................................... 100
Measurement of Screens ...................................................................... 101
Screen Frames ..................................................................................... 101
Mortar Box Covers .............................................................................. 102
Screen Cover/Splashboard .................................................................... 102
Water Supply ........................................................................................ 102
Group 3: The Lifting Mechanism ............................................................ 103
Camshaft ............................................................................................. 103
Cams .................................................................................................... 104
Cam Design & Drop Heights ................................................................ 105
Cam Mounting .................................................................................... 109
Drop Order .......................................................................................... 111
Group 3: The Stamps ............................................................................ 113
The Stem ............................................................................................. 114
The Tappet .......................................................................................... 115
The Stamp Head .................................................................................. 116
The Shoe .............................................................................................. 117
The Die ................................................................................................ 119
Chapter 6 ............................................................................................ 121
Other Battery Processes: ....................................................................... 121
Pre- and post-crushing treatment, other forms of crushing plant, gold recovery, power supply
............................................................................................................. 121
Pre-treatment ....................................................................................... 121
Ore Roasting ......................................................................................... 121
Battery House Processes ...................................................................... 123
Preliminary Sizing ................................................................................. 124
Rock Breaking ..................................................................................... 124
Ore-Feeders ......................................................................................... 125
The Crushing Stage ................................................................. 125
Roller Mills (side rollers) .......................................................... 126
Roller Mills (parallel rolls) ....................................................... 126
Centrifugal Roller Mills: The Huntington Mill ......................... 127
Grinding & Amalgamating Pans .............................................. 128
The Berdan ............................................................................ 130
Ball & Tube Mills .................................................................... 131
Post crushing Ore Treatment .................................................. 132
Gravity Separation .................................................................. 132
Blanket & Riffle Tables ........................................................... 132
Buddles ............................................................................... 133
Vanners & Shaking Tables ....................................................... 134
Moving Belt Vanners; the Frue Vanner .................................... 134
The Wilfley Table .................................................................... 135
Mercury Amalgamation ............................................................ 135
Recovery & Processing of Amalgam ........................................ 137
Amalgamating & Clean-up Pans .............................................. 137
Clean-up (Amalgamation) Barrels .......................................... 137
Processing of Mercury Amalgam ............................................. 137
Problems with Mercury Amalgamation ................................... 138
Chemical Gold Recovery Processes ......................................... 139
Chlorination & Lixiviatiion ....................................................... 139
The Cyanide Process ................................................................ 140
New Zealand’s First Commercial Cyanide Plant ...................... 140
The Widespread Adoption of the Cyanide Process .................. 141
Developments in the Cyanide Process ..................................... 143
Re-Processing of Tailings ....................................................... 144
Smelting ............................................................................... 144
Power .................................................................................. 145
Animal & Man Power ............................................................. 145
Wind Power .......................................................................... 145
Water Power .......................................................................... 146
Waterwheels ......................................................................... 146
Whitelaw Turbine ................................................................... 147
Pelton Wheel ......................................................................... 147
Steam Engines ....................................................................... 148
Internal Combustion Engines .................................................. 148
Electric Power........................................................................................................149
Chapter 7 ..................................................................................................................151
The Archaeological Survey: .......................................................................................151
Sample Size, Taphonomy, Bias, Site Survey Methodology ........................................151
Sample Size & Representativeness .............................................................................154
Taphonomy, Site Survival & Sources of Sample bias ..................................................156
Site Survey Methodology ..........................................................................................161
Weight Calculations ..................................................................................................162
Summary: The Representativeness of the Archaeological Record .............................162
Chapter 8 ...................................................................................................................165
The Archaeological Evidence: the Stamp Mill in Detail ............................................165
Group 1:  The Frame.................................................................................................165
The Lower Framework ...............................................................................................165
  Timber Foundations: Mud Sills & Cross (or Streak) Sills ......................................165
  Concrete Foundations ............................................................................................168
The Upper Framework ...............................................................................................171
Timber Frames ..........................................................................................................171
  A-Frame Mills ........................................................................................................171
Vertical Battery Posts/Kingposts ..............................................................................175
Braced Vertical Post Frame ......................................................................................175
Vertical Battery Post, Timber Braces ......................................................................175
Vertical Battery Post, Iron Braces ...........................................................................177
Vertical Battery Post, Knee Frame .........................................................................178
Vertical Battery Post, Trestle Frame .......................................................................181
Vertical Battery Post, Mounted on Mortar Box .......................................................184
Single Post Frames ..................................................................................................184
Double-Post Frames ...............................................................................................185
Iron Frames ..............................................................................................................186
Stamp Guides ...........................................................................................................190
Group 2:  The Mortar ...............................................................................................193
  Vertical Timber Mortar Blocks .............................................................................193
The Mortar Box .........................................................................................................195
  Material .................................................................................................................195
Timber Mortar Boxes ...............................................................................................195
Iron Mortar Boxes ....................................................................................................197
Sectional Mortar Boxes ............................................................................................197
Fabricated Steel Plate ...............................................................................................199
# Chapter 9

## The Crushing/Grinding Stage

### Pre-Group 4: Ashcroft’s Crusher

- McKay & Watson
- Other Grinding Pans

### Ore & Concentrate Roasting

- The Berdan
- The Dies
- The Shoe
- The Stamps
- Lifting Mechanism

### Group 3: The Lifting Mechanism

- The Camshaft
- The Cam
- Lateral Thrust
- Cam Mounts
- Drop Order

### Group 4: The Stamps

- The Stem
- Tappets
- The Stamp Head
- The Dies

## Chapter 9

The Archaeological Evidence: The Milling Circuit & The Complete Mill

### Pre-Treatment

- Ore & Concentrate Roasting
- Preliminary Sizing
- Ore Feeders

### The Crushing/Grinding Stage

- Centrifugal Roller Mills: The Huntington Mill
- The Berdan
- Other Grinding Pans
- McKay & Watson-Denny Pans
- Ashcroft’s Crusher
Appendices

Appendix A - Detailed Descriptions & Histories of Battery Sites ........................................350
North Island Sites ................................................................................................................351
Government Battery, Coromandel .....................................................................................354
Lillis Battery, Coromandel .................................................................................................359
Prospector’s Battery at the Coromandel School of Mines ..............................................367
Moewai Battery ..................................................................................................................369
Iris Battery Parts ..............................................................................................................372
Welcome Jack Battery, Coromandel ..................................................................................376
Whangamata Gold Corporation Battery (Luck at Last Reduction Works) ....................378
Government Battery, Mahakirau ......................................................................................381
Battery Creek Battery .......................................................................................................383
Hauraki Prospector’s Association (Reconstructed Battery) .............................................386
Sawyer’s Battery (at Hauraki Prospector’s Association, Thames) ..................................389
Thames Township Sign (Reconstructed Battery) ..............................................................391
Union Battery, Waihi .......................................................................................................393
Victoria Battery, Waikino ..................................................................................................395
Maratoto Gold-Mining Company’s Pan Amalgamation Plant, McBrinn’s Creek ..........400
Railey’s Battery/First Crown Battery, Karangahake .......................................................405
Second Crown Battery & Cassel Company Cyanide Plant, Karangahake ......................412
Cherry & Sons Battery, Karangahake ...............................................................................415
Talisman Battery, Karangahake .........................................................................................417
Woodstock Battery, Karangahake ....................................................................................421
Bendigo Battery, Waiorongomai Valley .........................................................................428
Ferguson’s New Era Reduction Works, Waiorongomai Valley ......................................434
Albion Battery, Terawhiti Station ......................................................................................441
Ashcroft’s Crusher, Phoenix Mine (Terawhiti Station) ....................................................445
South Island Sites .............................................................................................................448
Canvastown Centennial Memorial (Relocated Battery) ..................................................449
Johnston’s United Battery, N.W. Nelson ..........................................................................451
Taitapu Battery, N.W. Nelson ...........................................................................................458
Golden Blocks Battery, NW Nelson ..................................................................................463
Waimea Battery (disassembled), Blue Creek ....................................................................467
Culliford Co. Battery, Blue Creek ....................................................................................470
Wellington Battery, Top Valley Stream ..........................................................................472
Red Queen Battery, Mokihinui River ..............................................................................476
Britannia Battery, Waimangaroa ................................................................. 479
Mitchell’s Gully Goldmine & Battery, Charleston ........................................ 484
Croesus Battery, Lyell .................................................................................. 485
Alpine Battery, Lyell .................................................................................... 488
Black’s Point Museum .................................................................................. 491
Snowy River Battery, Waiuta ......................................................................... 492
Bolitho’s/Watts’ Battery, Lankey’s Creek, Reefton .......................................... 499
Inglewood Battery, Reefton .......................................................................... 502
Ajax Battery, Reefton .................................................................................... 505
No. 2 South Larry’s (Caledonian) Battery, Larry’s River ............................... 509
Kirwan’s Reward/Lord Brassey Battery ........................................................ 513
Union Battery, Devil’s Creek, Reefton .......................................................... 519
A1 (Last Chance) Battery, Big River Road .................................................... 522
Golden Lead Battery ..................................................................................... 524
Big River Battery, Big River ......................................................................... 528
Alexander Battery & Edwards Roasting Furnace, Alexander River .............. 538
Garden Gully Battery, Croesus Track ............................................................. 542
Moonlight Battery, Moonlight Creek ............................................................ 547
Mount Greenland Battery, Cedar Creek, Ross .............................................. 548
Callery’s Battery, Golden Point Historic Reserve, Macraes Flat ................. 552
Horse Flat (Deep Dell) Battery, Macraes ..................................................... 560
Bonanza Mine Huntington Mill (now at Golden Point Reserve) ................ 564
Bickerton’s Battery, Nenthorn ...................................................................... 567
Golden Bar Battery, East Otago .................................................................... 570
Stoneburn Battery, East Otago ...................................................................... 576
Buckland’s Battery, Barewood ...................................................................... 578
Fraser’s Gully Battery, Hindon ..................................................................... 581
Golden Gully Battery, Serpentine ................................................................ 585
Alpine Battery, Obelisk Range .................................................................... 589
White’s Reef Battery, Obelisk Range ............................................................. 594
Young Australian Battery & Water Wheel, Carrick Range ........................... 597
Heart of Oak/Star of the East Battery, Carrick Range .................................. 602
Smith’s Gully Battery, Carrick Range ............................................................ 605
Carrick Battery, Smith’s Gully, Bannockburn ............................................. 607
Come-in-Time Battery, Bendigo ................................................................... 609
Alta Battery, Bendigo ................................................................................... 613
Rise & Shine Battery, Bendigo ...................................................................... 615
Southberg’s Battery ........................................................................................................619
The Phoenix Company, Skippers Creek .........................................................................622
Crystal Battery, Sawyers Creek, Skippers .......................................................................636
Leviathan Battery, Skippers .............................................................................................640
Eureka Battery, Jennings Creek, Skippers .......................................................................642
Pleasant Creek Battery, Skippers .....................................................................................645
Currie’s Battery, Skippers .................................................................................................647
McNichol’s Battery, Aurum Basin, Skippers ....................................................................650
Nugget Battery, Shotover River .......................................................................................652
Anderson’s Battery, Richburn, Macetown ......................................................................658
Homeward Bound Battery, Richburn, Macetown .............................................................662
Tipperary Battery, Macetown ..........................................................................................669
United Goldfields Battery, Macetown .............................................................................672
All Nations Battery, Macetown ......................................................................................676
Sunrise Battery, Macetown ..............................................................................................679
Maryborough/Premier Battery, Sawyer’s Gully, Macetown .............................................681
The Invincible Mine & Battery, Rees Valley, Wakatipu ..................................................689
OPQ (Otago Pioneer Quartz) Battery, Waipori ..............................................................697
Victory Battery (Water Wheel), Waipori .........................................................................702
Canton Battery, Waipori ...................................................................................................705
Cosmopolitan Battery, Lammerlaw Stream, Waipori ....................................................709
Bella Reef Battery, Waipori ..............................................................................................713
Burn Creek Battery, Waitahuna .......................................................................................716
Printz’s Battery, Longwood Range ................................................................................719
Arethusa Battery, Longwoods ........................................................................................727
Alpha Battery, Preservation Inlet ......................................................................................730
Golden Site Battery, Wilson’s River, Preservation Inlet ..................................................734
Morning Star Battery, Preservation Inlet .........................................................................741
Crown Battery, Cuttle Cove, Preservation Inlet ..............................................................746
Appendix B ......................................................................................................................750
Technical details of stamp mills, based on archaeological observations ..........................750
Appendix C .....................................................................................................................759
Glossary of terms ............................................................................................................759
References ......................................................................................................................765
List of Figures

Figure 1. The Serpentine Battery in Otago, New Zealand. ............................................................. 1  
Figure 2. A steam engine of 1780 (Bourne 1868). ..................................................................... 8  
Figure 3. The ‘Euston Arch’ at Euston Station in London (Hudson 1965). .............................. 10  
Figure 4. The system of shafts and adit levels in a mine (Gordon 1906). ..................................... 27  
Figure 5. The timbering of a stope in a mine (Gordon 1906). ..................................................... 28  
Figure 6. An example of an animal-powered arastra (Gowland 1914). ........................................ 29  
Figure 7. Anvil stones from (A) Bachicon de Fresnedo (Portugal), and (B) Forno dos Mouros (Spain) (Burnham 1997). .................................................................................. 33  
Figure 8. Carreg Pumsaint, at Dolaucothi in Wales (Photo: Nigel Davies, www.geograph.org.uk/photo/396874). ..................................................................................... 33  
Figure 9. A vertical pestle mill dated to ca. 1430 (Needham 1965: Figure 619). ......................... 35  
Figure 10. A mid-sixteenth century stamp mill for dry crushing, as illustrated in Agricola’s De Re Metallica (Agricola 1950). ................................................................. 36  
Figure 11. A mill designed for wet crushing as illustrated in Agricola’s De Re Metallica (Agricola 1950). ........................................................................................................ 36  
Figure 12. Mortarstone (anvil stone) at Runnage on Dartmoor, Devon (Newman 1998). ...... 37  
Figure 13. Cornish stamp mill as illustrated in Pryce’s Mineralogia Cornubiensis of 1778. ....... 38  
Figure 14. A cross-section of a set of nineteenth century tin stamps (Andre 1878). ................. 38  
Figure 15. Cross-section of ‘earliest Californian mill’ erected by W.S. Moses (Del Mar 1912). .... 39  
Figure 16. The evolved form of the California Mill (Andre 1878). ............................................. 41  
Figure 17. Stevens’ patent stamp mill, Victoria Patent No. 112/122, 1858 (Davey 1988). .... 43  
Figure 18. The Great Expectations Battery at Thames in 1867 (Auckland Weekly News 20th December 1906, Sir George Grey Special Collections, Auckland Libraries, AWNS-19061220-8-2) .................................................................................................................. 44  
Figure 19. Early alluvial gold mining in Australia (Garran 1886). ............................................... 47  
Figure 20. The storming of the Eureka Stockade in December 1854 (Garran 1886). ............. 48  
Figure 21. The Port Philip & Colonial Gold Mining Company’s operation at Clunes (Garran 1886). ................................................................. 49  
Figure 22. The largest battery in the world in 1911, the Central Mill at Randfontein, Johannesburg (Sir George Grey Special Collections, Auckland Libraries, AWNS-19111012-2-1) .............................................................................................................................. 50  
Figure 23. The mineral deposits in the North Island (New Zealand Mines Record, 1906) .... 51  
Figure 24. The mineral deposits in the South Island (New Zealand Mines Record, 1906). .... 52  
Figure 25. Gabriel’s Gully in 1862 ......................................................................................... 54  
Figure 26. “Gold-diggers out prospecting” (Illustrated London News, 1863). ......................... 55  
Figure 27. “The famous Caledonian Mine” (Weston 1927). ................................................... 56  
Figure 28. Fern Spur Incline on the Piako County Council tramway at Waiorongomai .... 58  
Figure 29. Gold production of New Zealand from 1860 until 1965 (Williams 1965). .......... 64  
Figure 30. The four main ‘groups’ in the stamp mill structure .................................................. 65  
Figure 31. An isometric view of a ‘back-knee’ frame battery showing the basic terminology according to Richards (1906), an American source .............................................................................. 67  
Figure 32. Front elevation of a ‘back-knee’ frame stamper battery showing terminology according to Truscott (1923), a British source ........................................................................... 68  
Figure 33. Side elevation of a ‘back-knee’ frame battery showing contemporary terminology according to Truscott (1923) .......................................................................................... 69
Figure 34. The Mine & Smelter Supply Company (1912) list of parts for a 10 stamp battery. ................................................................. 71
Figure 35. The Keep it Dark Battery near Reefton (Galvin 1906). ................................................................. 72
Figure 36. A stamp mill with the main foundation structure shaded (adapted from Richards 1906). ................................................................. 73
Figure 37. The Hall Stamp Mill, Dahlonega District, Georgia, America (Richards 1906). ................................................................. 74
Figure 38. A ten stamp back-knee battery shown with timber or concrete foundations (The Mine & Smelter Supply Co. 1912). ................................................................. 75
Figure 39. Battery frame variations from Richards (1906). ................................................................. 77
Figure 40. Battery frame variations from Richards (1906). ................................................................. 78
Figure 41. Front and side elevations of a 5 stamp A-frame mill (ILT 1902). ................................................................. 79
Figure 42. Cross-section of an ‘A’ frame battery, with the notable lack of a vertical battery post (Del Mar 1912). ................................................................. 79
Figure 43. A cast iron framed battery (Louis 1902). ................................................................. 80
Figure 44. A steel stamp frame manufactured by the Union Iron Works of San Francisco (Richards 1906). ................................................................. 81
Figure 45. Side elevation of a cast iron framed battery from the Victoria Foundry, Bendigo, Australia (Rickard 1898). ................................................................. 81
Figure 46. Portable stamp mills from the Mine and Smelter Supply Company Catalog No 22 of 1912................................................................. 82
Figure 47. Triple-discharge two stamp mill by Joshua Hendy Machine Works, San Francisco (Richards 1906: 209). ................................................................. 82
Figure 48. Various types of stamp guide (Gordon 1906). ................................................................. 83
Figure 49. Various types of stamp guides from Richards (1906). ................................................................. 83
Figure 50. Front elevation of timber stamp frame sectioned to show mortar block construction detail (Gordon 1894 with annotation). ................................................................. 85
Figure 51. The North Star stamp mill in Grass Valley California, with 14 feet long timber mortar blocks (Abadie 1895; Richards 1906). ................................................................. 85
Figure 52. Isometric view of a concrete mortar block (Richards 1906). ................................................................. 86
Figure 53. Concrete mortar block with the anchor bolts running in outside channels (Caldecott 1909). ................................................................. 87
Figure 54. Concrete mortar block showing vertical anchor bolts cast into the block (left) and set within pipes (right) (Del Mar 1912). ................................................................. 87
Figure 55. A cast iron anvil block placed between the mortar box and concrete mortar block (Caldecott 1909). ................................................................. 88
Figure 56. Cross-section of the stamp battery of the Simmer and Jack Proprietary Mines, Germiston, South Africa (Schmitt in contributed remarks p. 97, Caldecott 1909). ................................................................. 88
Figure 57. Cut-away drawing showing how the stamps, dies and screens fitted in a typical iron mortar box (ILT 1902). ................................................................. 89
Figure 58. Sections of the Homestake Mortar (Richards 1906). ................................................................. 90
Figure 59. A cross-section of a stamp mill with a timber mortar box (Richards 1906). ................................................................. 90
Figure 60. A sectional mortar box (Mine & Smelter Supply Co. 1912). ................................................................. 91
Figure 61. Mortar box section, showing the locations of the ore feed at the rear and the screen at the front (adapted from ILT 1902). ................................................................. 92
Figure 62. Cross-section of a mortar box (adapted from Richards 1906) with annotations showing the Depth of Discharge. ................................................................. 93
Figure 63. A cross-section of a mortar designed for inside amalgamation, with copper plates mounted both back and front (adapted from ILT 1902). ................................................................. 94
Figure 64. Mortar box fitted with liner-plates under the ore feed and along the ends and sides (adapted from Truscott 1923). ................................................................. 95
Figure 65. The location and mounting of a single inclined front screen (adapted from ILT 1902). ................................................................. 96
Figure 66. Sections through double-discharge mortar boxes (ILT 1902). ................................................................. 97
Figure 67. A double discharge mortar as used at the Harriettville Mill, Victoria (Rickard 1898). ................................................................. 97
Figure 68. A cross-section of mortar box showing the screen angle (adapted from ILT 1902). ................................................................. 99
Figure 69. Perforated metal sheet screens (ILT 1902; Richards 1906). ................................................................. 100
Figure 70. Woven wire screens (Truscott 1923: 221) ................................................................. 100
Figure 71. A wooden frame for wire mesh screen (adapted from Rickard 1898) ................................................................. 102
Figure 72. A camshaft with drive pulley and five cams mounted (Clark 1904) ................................................................. 103
Figure 73. Cam shaft bearings (Mine & Smelter Supply Co. 1912: Richards 1906) ................................................................. 104
Figure 74. Side and end elevations of a cam with stiffening webs (ILT 1902) ................................................................. 104
Figure 75. An involute curve (ILT 1902) ................................................................. 105
Figure 76. The involute curve applied to a cam (Richards 1906 with annotations) ................................................................. 106
Figure 77. Graph of stamp lift, drop and rebound (Truscott 1923: 154) ................................................................. 106
Figure 78. The effect of lateral thrust (left) and right and left handed cams (Richards 1906) ................................................................. 108
Figure 79. A ten stamp camshaft with both left and right hand cams (Gordon 1894) ................................................................. 108
Figure 80. Camshaft with keyways cut for ten stamps and a drive pulley (Richards 1906) ................................................................. 109
Figure 81. Basic cam with two keyways (Louis 1902) ................................................................. 109
Figure 82. The US patent drawings for the Blanton Cam (Blanton 1902) ................................................................. 110
Figure 83. Stamp shoe and die sizes in the Mine & Smelter Supply Co. catalogue (1912) ................................................................. 110
Figure 84. The numbering of stamps (adapted from Clark 1904, advertisement for W. Anderson & Sons) ................................................................. 111
Figure 85. A cross-section through a stamp mill (adapted from Rickard 1898) ................................................................. 113
Figure 86. A standard straight stamp stem, with a taper at each end (Gordon 1894) ................................................................. 114
Figure 87. Simple one-sided collar tappet held in place by a key (Louis 1902) ................................................................. 115
Figure 88. Screw-mounted tappet and screw stem detail (Louis 1902) ................................................................. 116
Figure 89. The Californian gib tappet (ILT 1902) ................................................................. 116
Figure 90. A cross-section of mortar box showing the head (boss) shoe and die (Rickard 1898) ................................................................. 117
Figure 91. Cross-section of a stamp head, showing the tapered holes for the stem and shoe, and the two drift-ways (marked ‘k’) (ILT 1902) ................................................................. 117
Figure 92. Stamp shoes (ILT 1902; Richards 1906) ................................................................. 117
Figure 93. Stamp shoe and die sizes in the Mine & Smelter Supply Co. catalogue (1912) ................................................................. 118
Figure 94. Two different die forms (ILT 1902) ................................................................. 119
Figure 95. A hand-rabbed reverberatory furnace (ILT 1902) ................................................................. 122
Figure 96. The Howell-White furnace, an example of a revolving roasting cylinder (ILT 1902) ................................................................. 123
Figure 97. Cross-section through a typical stamper battery (ILT 1902 with annotations) ................................................................. 123
Figure 98. The Blake rock breaker ( Mine & Smelter Supply Co. 1912) ................................................................. 124
Figure 99. The Challenge, Roller and Tulloch ore feeders (Gordon 1906) ................................................................. 125
Figure 100. Cross-section of slow-speed Chilean Mill (Truscott 1923) ................................................................. 126
Figure 101. The Cyclone roller quartz crusher (AJHR 1888 C5) ................................................................. 126
Figure 102. Cut-away drawing of a Huntington Mill (ILT 1902) ................................................................. 127
Figure 103. Cross-section through a basic Wheeler Pan (Truscott 1923) ................................................................. 128
Figure 104. Cross-section through the McKay grinding and amalgamating pan (AJHR 1887) ................................................................. 128
Figure 105. Cross-section of separating pan (AJHR 1887) ................................................................. 129
Figure 106. Ferguson’s New Era Works, Waiongongma Valley (AJHR 1887 C5).      129
Figure 107. The original US Patent drawings of the Berdan grinding and amalgamating pan (Berdan 1853). 130
Figure 108. Cross-section of a typical tube mill (Gowland 1914).                        131
Figure 109. The Hardinge Conical Mill (Truscott 1923).                                  132
Figure 110. An outward-flow (convex) buddle in Devon in about 1912 (Greeves 2001).      133
Figure 111. Fre Vanner (Gordon 1906).                                                  134
Figure 112. The Wilfley Table (Mine & Smelter Supply Co. (1912).                     135
Figure 113. Mercury amalgamating tables (Richards 1903).                             136
Figure 114. A clean-up (amalgamating) barrel (Mine & Smelter Supply Co. 1912)       137
Figure 115. Amalgam strainer and safe (ILT 1902). 138
Figure 116. Mercury retort and condensing tube (ILT 1902).                            138
Figure 117. Cyanide tank and precipitating towers erected for the Crown Mine in 1889 (AJHR 1890 C3). 140
Figure 118. Plan and elevation of a 75 ton per day cyanide plant (Gowland 1914).     142
Figure 119. Zinc precipitation box (ILT 1902).                                         143
Figure 120. (Right) Cross-section of a Brown agitator (Gowland & Bannister 1930).    143
Figure 121. The Waithi Mining Company’s Brown (or B&M) agitator tanks at the Victoria Battery, Waikino (Gowland & Bannister 1930). 144
Figure 122. The three main types of water wheel (Oberg & Jones ed. 1917).             146
Figure 123. Plan and elevation of the Whitlaw Turbine (Glynn 1872).                   147
Figure 124. Simplified side elevation and plan of the Pelton Wheel (Oberg & Jones ed. 1917). 147
Figure 125. Pelton wheel in timber frame with timber housing (Mine & Smelter Supply Co., 1912). 148
Figure 126. Locations of North Island sites.                                           151
Figure 127. Locations of South Island sites.                                           152
Figure 128. Locations of sites in the Reefton area, West Coast.                       153
Figure 129. Locations of sites in the Skippers and Macetown areas, Otago.             153
Figure 130. The interior of the restored Coromandel Government Battery (site T10/1115) in 2011. 156
Figure 131. The United Goldfields Battery (site F41/484) near Macetown in Otago in 2011. 156
Figure 132. Anderson’s Battery (site F41/473) at Macetown soon after the battery house had collapsed (Lakes District Museum, EL0591). 158
Figure 133. Kirwan’s Reward Battery (site L30/62) near Reefton in 1998.               158
Figure 134. The remains of the Ajax Battery near Reefton in 2011.                      159
Figure 135. The Mayclaire Collection of battery equipment laid out at the Victoria Battery site in the early 1980s (Waihi Leader postcard). 160
Figure 136. The parts of the Iris Battery at the Opotunui Battery site in 2011.         161
Figure 137. The Alpine Battery (site F42/265) foundations in 2011.                    166
Figure 138. The Golden Lead Battery (site L31/29) on the West Coast (Petchey 1998b; J. Staton pers. comm. 2013). 167
Figure 139. The exposed foundation timbers of Johnston’s United Battery (site M25/73) in 2011. 167
Figure 140. Plan and elevation (left) and isometric drawing (right) of the foundations of the left hand section of Johnston’s United stamp mill (site M25/73) (P. Petchey & S. Bagley). 168
Figure 141. The United Goldfields Battery (site F41/484) at Macetown in 2011.         169
Figure 142. The concrete foundations for the Stoneburn Battery (site I43/75) in East Otago. 169
Figure 143. The surviving foundations of the Victoria Battery stamp mill (site T13/300) in 2011. ................................................................. 170
Figure 144. Timber and concrete mortar blocks at the Snowy River Battery (site L31/37) in 2011................................................................. 170
Figure 145. The Golden Site stamp mill (site B46/88) in Fiordland. ......................... 172
Figure 146. Elevations of the Golden Site stamp mill. ......................................... 172
Figure 147. An end view of the A-frame of the United Goldfields Battery (site F41/484) at Macetown in 2011.................................................... 173
Figure 148. The collapsed Fraser’s Gully stamp mill (site I44/517) in 2010. ................ 174
Figure 149. Reconstruction of the Fraser’s Gully stamp mill.................................. 174
Figure 150. Kirwan’s Reward battery (site L30/62) (Petchey 1998a; J. Staton pers. comm. 2013). ................................................................. 176
Figure 151. The Nugget Battery (site F41/23) in 2011............................................. 176
Figure 152. (Right) McNichol’s Battery (site E40/34), probably in the 1990s (Department of Conservation) ...................................................... 177
Figure 153. The remains of the A1 battery (site L31/27) in about 1975 (J. Staton, Department of Conservation) ...................................................... 178
Figure 154. The Grand Junction battery at Waihi under construction, showing the knee-frame structure(Sir George Grey Special Collections, Auckland Libraries, AWNS-19050914-10-3). ................................................................. 179
Figure 155. A ten stamp back-knee frame stamp mill as built by the Sandycroft Foundry Company Limited of Chester, England (Louis 1902: 238) ................................................................. 180
Figure 156. The Homeward Bound Battery (site F41/477) in 2011. .......................... 180
Figure 157. Elevation of a back-knee frame battery (Truscott 1923) and side view of the Homeward Bound Battery in 2011. ................................. 181
Figure 158. Front and side elevations of the Canton Battery (site H44/831) at Waipori. .... 182
Figure 159. The Canton Battery (site H44/831) in 2010. ....................................... 182
Figure 160. The Crystal Battery (site E41/91) at Skippers in 1993. ............................ 183
Figure 161. One of two remaining battery frames at the Union Battery (site L30/65), Globe Hill, Reefton, in 1994............................................. 183
Figure 162. The Come in Time Battery (site G41/251) in 1995. ................................. 184
Figure 163. The mortar box from the Arethusa Battery (site D46/161). ..................... 185
Figure 164. (Left) The Eureka Battery, probably in the 1960s (Lakes District Museum EL2679). ................................................................. 186
Figure 165. (Right) The Eureka Battery (site E41/51) in 2010. ................................. 186
Figure 166. (Left) Type 1 cast iron battery post. .................................................. 188
Figure 167. (Right) Type 1A cast iron battery post. ............................................ 188
Figure 168. (Left) A dismounted Type 1A battery post, at the Wellington Battery (site O28/47). ................................................................. 188
Figure 169. Type 2 cast iron battery post............................................................ 189
Figure 170. Type 3 iron framed prospectors’ mill. ................................................ 189
Figure 171. Type 4 cast iron battery posts............................................................ 190
Figure 172. The upper stamp guide of the All Nations Battery at Macetown (site F41/483). 191
Figure 173. The top stamp guides on the Nugget Battery beside the Shotover River (site F41/23)................................................................. 191
Figure 174. Cast iron top stamp guide at Printz’s Battery in the Longwood Range (site D46/150). ................................................................. 192
Figure 175. The Rise & Shine battery frame, showing the iron stamp guide mounted on the timber guide beam (Marion Sutton, DoC). ............................ 192
Figure 176. Two iron stamp guide mounts from the Roberts Brothers’ battery (ex-site T12/704).

Figure 177. Conventional timber mortar blocks at the Come in Time Battery, Bendigo (site G41/251) in 1998.

Figure 178. Mortar blocks and mortar box at the Garden Gully Battery (site K31/51) in 2011.

Figure 179. Mortar block from the disassembled Alpine Battery (site F42/265).

Figure 180. Detail of an 1880 photograph of Printz’s Battery under construction, showing the two mortar boxes with extended tops (Hall-Jones 1982).

Figure 181. Mortar box at Printz’s Battery (site D46/150) in 2011.

Figure 182. ‘Tiger’ Beale’s Pleasant Creek Battery (site E41/82) at Skippers in the 1970s (E. Warburton).

Figure 183. The remains of the Pleasant Creek Battery mortar box in 2011.

Figure 184. One of the 5 stamp sectional mortar boxes at the Phoenix/Achilles Battery (site E40/40).

Figure 185. The disassembled 2 stamp mortar box at the Smith’s Gully Battery (site F42/101) in 2010.

Figure 186. The mortar box at the Red Queen (site L28/24) in 2011.

Figure 187. The mortar box mounts on the cast iron battery posts at the Battery Creek Battery (site T12/1410).

Figure 188. A welded steel mortar box in the Mayclaire Collection at the Victoria Battery site, Waikino.

Figure 189. Typical one-piece cast iron mortar boxes, with mounts for vertical bolt-on screen frames.

Figure 190. The single stamp mortar box at the Sawyer’s Battery (site T12/1411), Thames.

Figure 191. The single mortars at the Mount Greenland Battery (site J33/39) in 1987 (J. Staton, Department of Conservation).

Figure 192. Single-stamp mortar at the Fraser’s Gully Battery, Hindon (site I44/517).

Figure 193. Small 2 stamp prospectors’ battery on display at the Canvastown monument.

Figure 194. Unprovenanced triple-discharge mortar box in the grounds of the Government Battery, Coromandel.

Figure 195. Fraser & Chalmers 2 stamp mortar box at the Golden Blocks Battery (site M25/81).

Figure 196. The “Riverside” 3 stamp mortar box in storage at the Thames School of Mines in 2011.

Figure 197. The cast iron sectional 4 stamp mortar box at the Culliford Battery (site M28/4) in 2011.

Figure 198. The left hand Homeward Bound (site F41/477) mortar box.

Figure 199. The Canton (site H44/831) mortar box in 2010.

Figure 200. Heavy 5 stamp mortar box manufactured at Waikino by the Martha Gold Mining Co.

Figure 201. Interior of mortar box at the Bendigo Battery (site T13/90), Waiorongomai, showing the full-width flare where amalgamation plates were probably mounted.

Figure 202. End view of the exterior of the Bendigo mortar box, showing the rear full-width flare (to the left in this view).

Figure 203. Wear from the splash of pulp on the interior of a mortar box at the Premier/Maryborough Battery (site F41/471).

Figure 204. Looking inside an Alpine Battery (site F42/265) mortar box, with rear and ore chute liners in place.
Figure 205. (Right) Side view of one mortar box at the Wellington Battery (site O28/47). The four bolts on the side secure an internal liner. ............................................................... 211
Figure 206. Triple-discharge (front and sides) mortar box on the Moewai Battery, at the Mercury Bay Museum. ................................................................. 212
Figure 207. (Right) The rear of the right hand mortar at the Serpentine Battery (site H42/2). ............................ 212

Figure 208. (Left) A.&G. Price mortar box dated 1875 with vertical screen mounts, on display at the Victoria Battery site, Waikino.................................................. 213
Figure 209. (Right) A.&G. Price mortar box dated 1898 with inclined slot screen mounts at the United Goldfields Battery (site F41/484), Macetown................................. 213
Figure 210. The right hand mortar box at the Come in Time Battery (site G41/251) in 1998. This box has vertical screen mounts, with parts of the screen frames still present. ......... 215
Figure 211. Wooden screen frame in the ‘Riverside’ mortar box. ......................................................... 215
Figure 212. A cast iron screen frame at the Battery Creek Battery (site T12/1410). .................. 215
Figure 213. Punched iron sheet screen at the Premier/Maryborough Battery (site F41/471), Macetown, in 2010.......................................................... 216
Figure 214. The camshaft bearing mount on Anderson’s Battery (site F41/473)......................... 218
Figure 215. Discarded cam at the Ajax Battery (site L30/31), near Reefton .................. 219
Figure 216. Lightweight cam from the Arethusa Battery, Longwood Range (site D46/161). .................. 220

Figure 217. Typical mid-size cam with plain arms, at the Alpine Battery (site F24/265).... 221
Figure 218. Heavy cams with strengthening webs at the Homeward Bound Battery (site F41/477). ................................................................. 221
Figure 219. A robust but short throw cam in the Union Iron Work’s prospectors’ battery at the Coromandel School of Mines. ............................................ 221
Figure 220. Worn cam at the Albion Battery (site Q27/112), Terawhiti. The wear is greatest at the point where the cam struck the tappet........................................ 222
Figure 221. Two cams with repairs riveted to their faces at the Young Australian Battery (site F42/25) in the Carrick Range......................................................... 222
Figure 222. The camshaft at the A1 Battery (site L31/27). A mixture of left hand and right hand cams are used in the same 5 cam group. ........................................ 223
Figure 223. The camshaft of the Eureka Battery (site E41/51) at Skippers. One left and one right hand cam are used. ................................................................. 223
Figure 224. A cam secured by a conventional key in a keyway on the Come in Time Battery at Bendigo (site G41/251). .............................................................. 224
Figure 225. A Blanton cam at the Eureka Battery, Skippers (site E41/51). .............................. 224
Figure 226. Basic collar tappets at the Cosmopolitan Battery (site H44/745).............. 229
Figure 227. A screw tappet and its mounting thread in almost perfect unworn condition on the Come in Time Battery (site G41/251).................................................. 229
Figure 228. Screw tappet with badly worn thread on Anderson’s Battery (site F41/473) at Macetown................................................................. 230
Figure 229. Gib tappet on a spare stamp assembly at Anderson’s Battery (site F41/473). .... 230
Figure 230. A stamp head from the Arethusa battery (site D46/161)................................. 231
Figure 231. Discarded worn out shoe with square shank at the Alta Battery, Bendigo (site G41/253). .......................... 231
Figure 232. Unused shoe with round shank at the Alta Battery, Bendigo. .......................... 231
Figure 233. Stamp heads and shoes from the Roberts Brothers’ Battery, now held by the Hauraki Prospectors’ Association in Thames........................................ 232
Figure 234. Unused and slightly used dies at the Taitapu Battery (site M25/86) in NW Nelson. .............. 232
Figure 235. A very unevenly worn die at the Snowy River Battery (site L31/37) near Waiuta. .................................................................233
Figure 236. The 1896 furnace and site of the stamp mill at the Tipperary Battery (site F41/485) in 1993. .................................................................236
Figure 237. One of the in-ground ore roasting kilns at the Victoria Battery (site T13/300). .................................................................236
Figure 238. The brickwork dust chamber and flue for the two rotary furnaces at the Whangamata Gold Corporation Battery (site T12/601). .................................................................236
Figure 239. The Alexander Mine ‘Edwards Roaster’ reverberatory furnace, built in 1934 (site L31/83). .................................................................237
Figure 240. The ore bin, grizzly and jaw crusher at Callery’s Battery (site I42/161). .................................................................238
Figure 241. The grizzly and small Ross jaw crusher at the Lillis Battery (site T10/773) in about 1996. .................................................................239
Figure 242. The Kincaid & McQueen Co. Ltd. jaw crusher at the Phoenix/Achilles Battery (site E40/40). .................................................................239
Figure 243. The ore feeder at Callery’s Battery (site I42/161). .................................................................239
Figure 244. One of the two Challenge ore feeders at the Homeward Bound Battery (site F41/477). .................................................................240
Figure 245. The discs from two Challenger ore feeders amongst debris at the Bendigo Battery, Waiorongomai (site T13/90). .................................................................240
Figure 246. The re-erected Bonanza at the Golden Point Reserve in Otago. .................................................................241
Figure 247. The Huntington Mill from the Bonanza Mine at Nenthorn. .................................................................241
Figure 248. The Berdan at Anderson’s Battery (site F41/473) in the 1970s (Lakes District Museum, EL0588). .................................................................242
Figure 249. The Anderson’s Battery Berdan frame, from measurements taken in 2010. .................................................................242
Figure 250. The two Bérards at the Lillis Battery (site T10/773) in 2012. .................................................................243
Figure 251. The row of seven Bérards at the Invincible Battery (site E40/58) in 1995. .................................................................243
Figure 252. The Maratoto Gold-mining Company’s pan amalgamation plant (site T13/276) in 2011. .................................................................244
Figure 253. The distinctive outlets of the separating pan at the Maratoto Gold-mining Company’s pan amalgamation plant. .................................................................244
Figure 254. The muller (rotor) from a McKay pan at the Woodstock Battery (site T13/289). .................................................................245
Figure 255. Watson & Denny patent pan manufactured by Chas. Judd of Thames. .................................................................245
Figure 256. The Ashcroft’s Crusher at the Phoenix Mill (site Q27/114) in 2011. .................................................................246
Figure 257. The modified tube mill at the Victoria Battery (site T13/300) in 2012. .................................................................246
Figure 258. The ball mill at the Lillis Battery (site T10/773) in 1996. .................................................................247
Figure 259. The Lillis ball mill in 2010. .................................................................247
Figure 260. The riffle tables at the Lillis Battery (site T10/773) in about 1996. .................................................................248
Figure 261. Amalgamating table at the Lillis Battery in 2010. .................................................................249
Figure 262. The amalgamating table at Callery’s Battery (site I41/161). .................................................................249
Figure 263. The 1899 Alpha Battery (site B46/42) in Fiordland in 2005. .................................................................249
Figure 264. The tables at the Homeward Bound Battery (site F41/477) in 2010. .................................................................250
Figure 265. The mercury trap at the Homeward Bound Battery (site F41/477). .................................................................250
Figure 266. The surviving table at Anderson’s Battery (site F41/473) in 2010. .................................................................251
Figure 267. The remains of the traps at the head of the table at Anderson’s Battery. .................................................................251
Figure 268. The 1884 circular convex table (site E40/59) below the Invincible Mine. .................................................................252
Figure 269. Vanner head in the collection of the Hauraki Prospectors’ Association in Thames. .................................................................252
Figure 270. The portable shaking table at the Lillis Battery (site T10/773) in 2010. .................................................................253
Figure 271. The Wilfley Table at Callery’s Battery (site I42/161) in 2011. .................................................................254
Figure 272. The frame for the Wilfley Table at the Homeward Bound Battery (site F41/477) in 2011................................................................. 254
Figure 273. A Wilfley table at Barewood in Otago in 1996................................................................. 255
Figure 274. The amalgamating barrel at the Young Australian Battery (site F42/25) .... 256
Figure 275. Mercury safe at the Taitapu Battery (site M25/86) .................................................. 256
Figure 276. Top of mercury retort at Fraser’s Gully Battery (site I44/517). ................................ 257
Figure 277. Bottom of mercury retort at the Premier/Maryborough Battery (site F41/471). 257
Figure 278. The furnace at the Taitapu assay house (site M25/182). ........................................ 257
Figure 279. In-ground circular timber cyanide sump at the Premier/Maryborough Battery (site F41/471). ............................................................................................................. 259
Figure 280. Two 20 feet diameter circular corrugated iron cyanide vats at the Bendigo Battery (site T13/90). ......................................................................................................................... 259
Figure 281. Tarred sheet iron cyanide vats at the Big River Battery (site L31/4) in 2011.... 260
Figure 282. The sheet iron cyanide vats at the Snowy River Battery (site L31/37). .......... 260
Figure 283. Concrete B&M agitator vats erected in 1895 at the Union Battery, Waihi (site T13/303). ................................................................................................................................. 261
Figure 284. Rectangular concrete in-ground cyanide sumps at the Whangamata Gold Corporation (Luck at Last) Battery (site T12/601) in 2011......................................................... 261
Figure 285. Isometric drawing of 1889 cyanide vat, extrapolated from 1889 AJHR partial drawing ..................................................................................................................... 262
Figure 286. Cathleen Haunan (NZHPT) sitting on what are probably the remains of a rectangular timber cyanide vat at Ferguson’s New Era Reduction Works (site T13/104) in 2012..................... 262
Figure 287. Concrete foundations for the sheet iron B&M agitator tanks at the Victoria Battery (site T13/300) in 2011 ..................................................................................................................... 263
Figure 288. Precipitation boxes at the Alexander Battery (site L31/12) in 2011. .................. 263
Figure 289. One of the two surviving precipitation boxes at Big River (site L31/4) in 2011. ................................................................................................................................. 264
Figure 290. The inclined chimney at the Tarawera Smelter (site B45/29) in Fiordland. ..... 265
Figure 291. The Invincible water wheel (site E40/58) in 1995. .................................................... 266
Figure 292. The small wooden Canton water wheel (site H44/831) in 1995. ......................... 267
Figure 293. The Young Australian water wheel (site F42/28) in 1993. ...................................... 267
Figure 294. The Victory water wheel (site H44/61) in 2010. ......................................................... 268
Figure 295. The improvised turbine wheel at the Fraser’s Gully Battery (site I44/517) in 1993. ................................................................................................................................. 269
Figure 296. The flat-vane wheel at the No. 2 South Larry’s Battery (site L30/7). .................. 269
Figure 297. The Whitelaw turbine at the Bella Reef Battery site (H44/556) in 2011. .... 270
Figure 298. The Whitelaw turbine runner (right) and mount (left) amongst the Waimea Battery parts (site M28/5). ............................................................................................. 270
Figure 299. Turbine runner (right) and compressed air receiver (left) in the streambed immediately downstream of the Phoenix/Achilles Battery (site E40/40) in 2011........ 271
Figure 300. Pelton wheel at the Whangamata Gold Corporation Battery (site T12/601)..... 271
Figure 301. The Pelton wheel at the Alpine Battery (site L29/3). .................................................. 273
Figure 302. The large Pelton wheel at the Woodstock Battery (site T13/289). ....................... 273
Figure 303. The Lancashire boiler and dismounted engine flywheels at Printz’s Battery (site D46/150). ..................................................................................................................... 274
Figure 304. The boiler and steam engine at the Albion Battery (site Q27/112). ................... 275
Figure 305. The Tangye single-cylinder horizontal engine at Callery’s Battery (site I42/161). ................................................................................................................................. 275
Figure 306. The twin cylinder Ruston engine at the Lillis Battery (site T10/773). .............. 276
Figure 307. The gas producer at Buckland’s Battery (site I43/99), Barewood
Figure 308. The disassembled Brush Corporation ‘Victoria’ electric motor at Bullendale (site E40/47).
Figure 309. The electrical control unit at the Premier/Maryborough Mine (site F41/480).
Figure 310. Sonar image of the Horahora Power Station (site T15/195) in Lake Karapiro, taken in 2011 (Tech Dive NZ).
Figure 311. David Petchey standing beside the most intact of the two surviving Siemens
B. & G. Price Pelton wheels from the Horahora Power Station in 2011.
Figure 312. The locations of the 8 case study sites.
Figure 313. The Nugget Battery (site F41/23) in 2011.
Figure 314. Mortar boxes, gears wheels and an amalgamating barrel built into the retaining wall at the Nugget Battery.
Figure 315. Two loose mortar box bottom sections in front of the Nugget Battery.
Figure 316. The abandoned Young Australian Battery and water wheel in 1939.
Figure 317. The Young Australian Water Wheel in 1993.
Figure 318. The Young Australian battery in 2011, from the same viewpoint as the 1936 image above.
Figure 319. Plan of the archaeological features at the Young Australian Battery in 2011.
Figure 320. A rear view of the Young Australian Battery in 2011, showing the A-frame, geared camshaft drive and the Berdan.
Figure 321. The camshaft and stamp stems in the Young Australian Battery in 2011.
Figure 322. The Albion Battery site in 2011.
Figure 323. Some of the dismantled battery posts and stamps from the Albion Battery.
Figure 324. The two Brush Corporation dynamos in the powerhouse in 1886 (Lakes District Museum, EL0967).
Figure 325. The Kincaid & McQueen rock breaker on a spur above the Phoenix/Achilles Battery site.
Figure 326. One of the surviving mortar boxes at the Phoenix/Achilles Battery.
Figure 327. The dismantled Brush Corporation Victoria electric motor at the New Main Shaft site.
Figure 328. The two Brush Corporation dynamos at the Phoenix power house site in 2011.
Figure 329. The two 1885 A.& G. Price Pelton wheels at the Phoenix power house site.
Figure 330. The Eureka Battery (site E41/51) in 2011.
Figure 331. The triple-discharge mortar box at the Eureka Battery.
Figure 332. The Homeward Bound Battery in 2011.
Figure 333. The rock breaker at the Homeward Bound Battery in 2011.
Figure 334. The concrete mortar block for the 1936 ten stamp addition to the Snowy River Battery.
Figure 335. The B&M Agitators for slimes treatment at the Snowy River Battery.
Figure 336. The Bendigo Battery under construction in 1910.
Figure 337. Plan of the archaeological features at the Bendigo Battery site in 2010.
Figure 338. Mortar box on its concrete foundations at the Bendigo Battery site in 2011.
Figure 339. The A.& G. Price camshaft at the Bendigo Battery site in 2011.
Figure 340. Three cyanide vats at the Bendigo Battery site in 2011.
Figure 341. Title page of a copy of Louis (1902), originally owned by Edgar Elliston.
Figure 342. The reconstructed stamp mill at Black’s Point Museum.
Figure 343. The original building of the Otago School of Mines.
Figure 344. The Thames School of Mines in about 1900 (AJHR 1902).
Figure 345. The Thames School of Mines in 2011.
Figure 346. The Fraser & Tinne 6 stamp mill at Printz’s Battery (site D46/150).
Figure 347. Advertisement for Fraser & Tinne (Thames Miners’ Guide 1868)................. 313
Figure 348. The site of the 1899 OPQ Battery at Waipori.............................................. 322
Figure 349. The boiler at the Ajax Battery (site L30/31) in 2011........................................ 323
Figure 350. Jitlada Innanchai standing on a bench cutting on the road to the Britannia Mine (site L29/15)................................................................................................................. 323
Figure 351. Abandoned parts from the Waimea Battery (site M28/5)................................. 323
Figure 352. Re-assembly marks carved into the frame of the Homeward Bound Battery (site F41/477).......................................................................................................................... 324
Figure 353. Roman numeral carved into a cross-sill at the Alpine Battery (site F42/265)...... 324
Figure 354. Worn out and discarded dies and shoes at the Snowy River Battery (site L31/37)................................................................................................................................. 325
Figure 355. A screw tappet on Anderson’s Battery (site F41/473) with a badly worn thread. 326
Figure 356. Almost unworn cams on the All Nations Battery (site F41/483) in Otago........... 326
Figure 357. A worn cam face on the Johnston’s United Battery (site M25/73) in Nelson...... 326
Figure 358. Repaired cams and tappet on the Young Australian Battery (site F42/25)........ 327
Figure 359. A hole (centre of photo) worn right through the side of the ore feed in one Big River Battery mortar box.............................................................. 327
Figure 360. Repair to a section of the Victory Water Wheel (site H44/61)......................... 328
Figure 361. A detail of the geared drive wheel at No. 2 South Larry’s Battery.................... 328
Figure 362. The turbine wheel at the No. 2 South Larry’s Battery....................................... 329
Figure 363. The Come in Time battery in 1993............................................................... 329
Figure 364. The broken ex-Phoenix Company powerhouse drive pulley at Currie’s Battery (site E40/24)......................................................................................................................... 330
Figure 365. ‘Tiger’ Beale’s Pleasant Creek Battery (site E41/82)....................................... 330
Figure 366. The Otago Pioneer Quartz (OPQ) battery under construction at Waipori in 1899. 331
Figure 367. The second 50 stamps being constructed at the Victoria Battery in 1898.......... 331
Figure 368. Using a lifting frame and chain block during the restoration of Kirwan’s Reward Battery (site L30/62) by the Department of Conservation in 2010 (J. Staton, DoC, Greymouth).................................................................................................................................. 332
Figure 369. The interior of Johnston’s United Battery (site M25/73).................................... 332
Figure 370. Department of Conservation staff working on Johnston’s United Battery (site M25/73) during its restoration in 2011................................................................. 333
Figure 371. A detail of the embossed maker’s mark on the mortar box manufactured at the Waikino Foundry................................................................. 333
Figure 372. A portable forge at Printz’s Battery (site D46/150)............................................ 334
Figure 373. Kevin Jones demonstrating the use of a forge on a New Zealand Archaeological Association fieldtrip.......................................................... 334
Figure 374. Block and tackle arrangements for 1 to 5 part lines (Oberg & Jones 1917)....... 335
Figure 375. Detail from the photograph of the OPQ Battery under construction.................. 336
Figure 376. The Homeward Bound Battery in 2011......................................................... 336
Figure 377. The Young Australian Battery camshaft (573 lb), cams (60 lb each) and stamps (565 lb)......................................................................................................................... 338
Figure 378. The probable forge at the Young Australian Battery site.................................. 339
Figure 379. The corrugated iron battery house of Callery’s Battery (site I42/161) at Macraes Flat................................................................. 340
Figure 380. The top of a mercury retort at the Johnston’s United Battery (site M25/73)....... 343
Figure 381. The Alexander Battery Edwards Roaster reverberatory furnace (site L31/83) in 2011 343
Figure 382. A pile of roasted concentrates at the site of the Alexander Battery Edwards Roaster. .................................................................344
Figure 383. The Snowy River cyanide plant (site L31/37). .................................................................345
List of Tables

Table 1. Battery terminology. ........................................................................................................... 70
Table 2. Typical mortar box dimensions. .......................................................................................... 92
Table 3. Typical mortar box weights in about 1900 (Louis 1902: 131). .............................................. 92
Table 4. Screen measurements. ........................................................................................................ 101
Table 5. Camshaft diameters for various stamp weights from Wiard (1915) and Richards (1906). ................................................................................................................................................ 104
Table 6. Stamp drops per minute and maximum height of drop (Truscott 1923: 154). ............... 107
Table 7. Cam diameters, tip to tip, for different weights of stamp and height of drop (Mine & Smelter Supply Co. 1912).................................................................................................................. 107
Table 8. Stamp drop orders, their reciprocals, the places where these orders are known to have been used, and the sources quoted. .......................................................................................................... 112
Table 9. Recommended and actual relative weights of stamp components from Louis (1902). 114
Table 10. Recommended relative weights of stamp components at various dates. ...................... 114
Table 11. Stamper battery numbers 1863-1909 ............................................................................. 155
Table 12. Foundation timber dimensions ......................................................................................... 166
Table 13. Stamp mill sites with concrete foundations. .................................................................... 169
Table 14. A-frame stamp mills recorded during the archaeological survey. ................................. 173
Table 15. Timber sizes in intact original A-frame batteries. ............................................................. 174
Table 16. Stamp mills with vertical battery posts and timber braces. ............................................. 175
Table 17. Timber dimensions in braced vertical post stamp mills .................................................. 177
Table 18. Stamp mills with vertical battery posts and iron braces. ................................................ 178
Table 19. Dimensions of the main structural elements in the Homeward Bound Battery ......... 181
Table 20. Stamp mills with vertical battery posts and trestle frames. ............................................. 183
Table 21. Dimensions of main timber elements from vertical post trestle frame mills .......... 183
Table 22. Mortar boxes with mounts for bolt-on battery posts. ..................................................... 185
Table 23. Double-post frame stamp mills ....................................................................................... 185
Table 24. Stamp mills with iron frames. .......................................................................................... 187
Table 25. Stamp mills with sectional mortar boxes. ....................................................................... 197
Table 26. Overall dimensions and manufacturers of single stamp mortar boxes. .................... 201
Table 27. Overall dimensions and manufacturers of two stamp mortar boxes. .......................... 202
Table 28. Overall dimensions and manufacturers of 3 stamp mortar boxes. .............................. 204
Table 29. Overall dimensions and manufacturers of four stamp mortar boxes ....................... 205
Table 30. Five stamp mortar boxes in New Zealand. ..................................................................... 206
Table 31. Sites with mortar boxes possibly designed for internal amalgamation .................... 210
Table 32. Multiple-discharge mortar boxes in New Zealand ....................................................... 212
Table 33. The distribution of vertical clamp-on screens and inclined slot screens by size of mortar box. .............................................................................................................................................. 213
Table 34. The distribution of mortar boxes with vertical and inclined screens by manufacturer, country of manufacture and date of manufacture, where these can be confidently determined. .......................................................................................................................... 214
Table 35. Camshaft diameters and calculated stamp weights from a sample of 16 surviving stamp mills. ............................................................................................................................................... 217
Table 36. Camshaft diameters for various weights of stamps from Wiard (1915) and Richards (1906), compared to the New Zealand archaeological evidence. .................................................... 218
Table 37. Cam sizes (tip to tip) in relation to stamp weight and camshaft diameters for a sample of 16 stamp mills. ......................................................................................................................... 220
Table 38. Stamp mills with mixed cams to control lateral thrust. ................................................. 223
Table 39. Stamp mills in which the Blanton-type cam was used. ................................................... 225
Table 40. Calculated stamp weights and details of main stamp components for 16 New Zealand stamp mills. ........................................................................................................... 227
Table 41. Ore and concentrate kilns and furnaces recorded during the archaeological survey. ................................................................. 235
Table 42. Rock breakers recorded in association with battery sites ................................................. 238
Table 43. Sizes and locations of amalgamating barrels ................................................................. 256
Table 44. Cyanide plants recorded during the archaeological survey. ........................................... 258
Table 45. Zinc precipitation box measurements .............................................................................. 264
Table 46. Water wheels (including fragmentary remains) recorded during the archaeological survey. ......................................................................................................................... 266
Table 47. Whitelaw turbines identified in the New Zealand goldfields. ........................................... 270
Table 48. Pelton wheels in the New Zealand goldfields ................................................................. 272
Table 49. Battery sites with substantial evidence of steam power plant ........................................ 274
Table 50. Manufacturers of battery machinery .............................................................................. 310
Table 51. The mechanical advantage of the block & tackle (Oberg & Jones 1917) ...................... 335
Table 52. Dimensions of Homeward Bound guide beam and stamp guides .................................. 337
Table 53. The power of men working at a crane (Clark 1897) ....................................................... 337
Table 54. Muscular Power of a Man and of Various Animals (Forbes 1965) .................................. 338
Table 55. Summary of volumes and weights of camshaft and cams at the Young Australian Battery. ......................................................................................................................... 338
Table 56. Noise measurements taken in operating stamper batteries in 2011 .............................. 341
Measurements

This thesis uses the imperial measurement system throughout, as this is the system in which all of the machinery under discussion was designed and built. This allows direct comparisons back to the contemporary engineering literature and mining reports. It must be remembered that while a stamp mill might be referred to in this literature as having a nominal 1250lb stamp, there was no such thing as a 566 kg stamp in 19th century New Zealand, and this type of direct conversion creates a spurious accuracy. Metric conversions are provided in Chapter 11, when the archaeological evidence is used to attempt to estimate the work that people did in the mills, and therefore relates to a modern interpretation of the historic workplace.

Similarly, all references to money and expenditure have been left in the original units of £ (pounds) s. (shillings) d. (pence). Any attempt to convert these to modern value equivalents is quickly out of date.

The following conversions cover the main units used here:

Weight (Avoirdupois: for dry goods and machinery)

1 pound (lb) = 0.45kg
1 long hundredweight (cwt) = 112 lb = 50.8kg
1 long ton = 20 cwt = 2240 lb = 1016kg

Weight (Troy: for gold)

1 pennyweight (dwt) = 1.555g
1 ounce (oz) = 20 dwt = 31.103g

Volume (for fluids)

1 gallon (imperial) = 4.55 litres
1 gallon (US) = 3.79 litres

Distance

1 inch = 25.4mm
1 foot = 12 inches = 304.8mm
1 yard = 3 feet = 914.4mm
1 mile = 1.6km

Power

1 horsepower (hp) = 746 watts
Chapter 1
Introduction

The stamp mill is one of the iconic features of old goldfields, standing gaunt and abandoned high in the mountains, or ‘rescued’ and re-erected in front of local museums. In New Zealand many Department of Conservation walking tracks make use of old goldfields roads, with stamper batteries as destinations or points of interest (Figure 1), and many people are familiar with these machines without necessarily knowing much about them. Examples are to be found in historic hard-rock mining districts around the world, and in particular in the sites of the nineteenth century Pacific Rim gold rushes of America, Australia and New Zealand.

![The Serpentine Battery in Otago, New Zealand.](image)

The stamp mill was a simple machine, designed to crush rock down to the consistency of sand so that any gold present could be recovered, and it was a robust machine, so many examples have survived. Its technological origins go back possibly 2,000 years, but it was in California in the 1850s that its ‘modern’ form emerged, to then be carried around the world, all the time undergoing a constant gradual evolution. It therefore makes an ideal subject for the archaeological study of the nineteenth century introduction and development of technology in New Zealand within a global context.

The archaeological study of post-medieval technology has been undertaken under a number of banners, including Industrial Archaeology (largely in Britain and America), Historical Archaeology (America, New Zealand and Australia) and Patrimoine Industriel (France). This thesis considers the topic under the overarching framework of Industrial Archaeology; it examines the history and archaeology of an industrial subject, considers the innovation, adoption and adaption of industrial technology, and finally reconstructs from archaeological evidence the experiences of industrial workers.
An Archaeological Approach

For research to be considered archaeological it must concentrate and build upon the physical archaeological evidence of a landscape, site, feature or artefact (Smith 1990: 86). The practice of modern archaeology effectively began with the work of Augustus Pitt-Rivers in England in the 1890s, and it was his detailed recording and interpretation of stratigraphy and context that set his work apart from earlier antiquarians (Pitt-Rivers 1897). Since then many aspects of archaeology have become more formalised and developed, but the basic focus on the physical evidence remains. However, the time period considered by archaeologists has continuously been extended, until the study of sites that were occupied within living memory (such as Second World War sites) is now widely accepted (eg Walton 1990).

At the same time as the overall discipline of archaeology has been evolving, the sub-discipline of Industrial Archaeology has emerged and created its own identity in the study of industrial sites, processes and communities. There have been numerous debates about its scope and subject matter (which are outlined below in Chapter 2), but one key issue has been the role of Industrial Archaeology in examining social issues, an issue that lies at the heart of all archaeology; as Mortimer Wheeler observed, archaeology should be about digging up people, not things (Wheeler 1956: preface). Initially this was addressed simply by considering workers’ housing, but more recent research has been more nuanced, with wider considerations of the social and cultural dimensions of the industrial landscape and workplace, (eg Labadi 2001; Mate 2010; Palmer 2005).

Almost all archaeologies of the post-Medieval ‘modern’ period have to consider the global linkages that were evolving, particularly during the 18th and 19th centuries, when movement of people, trade goods, raw materials and technology increased as international shipping became faster, safer and cheaper. Some aspects of material culture appear around the world; for example British-made patterned ceramics from Staffordshire can be found in historical archaeological sites in America, Australia, New Zealand and Canada as well as in their home country, and various theoretical approaches have emerged that consider these global (and often capitalist) connections (Orser 2008, 2009a, 2009b; Woods 2013: 93, Table 16). In New Zealand there has been an increasing body of work that not only considers the development of the country, but also focuses on the linkages between colonial New Zealand and the rest of the world (eg Campbell & Furey 2013; Garland 2012; Petchey 2013).

One of the on-going challenges facing archaeology when attempting to address large scale or global issues is its focus on the single site, often as a result of the physical requirements of archaeological excavation (Orser 2008: 25, 32; 2009b: 261). Industrial Archaeology, with its focus on standing structures and surviving machinery as well as traditional sub-surface evidence provides an excellent opportunity to consider large numbers of sites in some detail without the need for intensive (and expensive) excavation. The standing remains of a machine (the stamp mill in the present context) constitute not just part of on archaeological site, but an artefact in that site as well. The machine (and its component parts) can be considered as material culture in the same way as any other artefact, and can be examined to determine its design, manufacture, modification, usewear, and function. This is conceptually no different to the examination of a lithic flake from a prehistoric site or a transfer-print plate from an historic site, and aligns the practice of Industrial Archaeology much closer to ‘conventional’ archaeology than it has often been considered in the past.
The Archaeology of Gold Mining & The Stamp Mill

A key series of events in the second half of the nineteenth century were the gold rushes to America, Australia, New Zealand and South Africa, and the archaeological study of gold mining technology has been of lasting interest in the first three of these places (eg Birmingham et al 1979; Field & Olssen 1976; Hamel 1983, 1994a, 1994; Hancox 1985; Hardesty 2010; Landon & Tumberg 1996; Moore & Ritchie 1996, 1998; Petchey 1994, 2002, 2006a; Ritchie 1981, 1985, 1990; White 2010). The social aspects of the goldfields have also been studied, originally probably more by economic historians (eg Fetherling 1997) than by archaeologists, but in the past 20 years a considerable body of archaeological work has built up that looks at social issues (Knapp 1998: 2). The earliest and most basic approach was simply to look at the housing and settlements of the miners (eg Bristow 1994, 1995; Petchey 1999; Ritchie 1980) but as the subject and its theoretical frameworks have developed more nuanced and sophisticated approaches have been taken, such as Mate’s (2010) recent work on the social meanings in an industrial archaeological landscape in Queensland, and White’s (2010) consideration of decision-making in an ageing stamp mill.

The stamp mill (also known as a ‘stamper battery,’ ‘stamper,’ ‘crushing battery,’ ‘battery,’ ‘cam-stamp mill’ or even simply ‘machine’) was at the heart of many hard-rock mining communities, because it was the place where the effort of all of the individuals involved came together to produce the final product: gold. The stamp mill was only part of the overall battery, which could include many other crushing and sorting processes, but as the largest, heaviest and most robust piece of equipment, it is the most common surviving element that is found today. It was also particularly enduring, being used in the very first crushing mills in New Zealand in the 1860s, and still being is employed at an industrial scale until the 1950s in the Victoria Battery at Waikino. It therefore fulfils two important criteria for archaeological study: a good representative sample, and a good chronological spread.

There have been many investigations into the development and operation of the stamp mill in different countries (eg Burt 2000; Davey 1988; Pearson & McGowan 2000; Petchey 1996a; White 2010), and some of these papers consider how the technology travelled around the various goldfields. There has, however, never been a comprehensive survey of these mills in New Zealand, and little collated data regarding their design, construction, condition or survival existed other than the site records held in the New Zealand Archaeological Association’s Site Record File (now digitised as Archsite). As a single site type with good survival and geographical and chronological spreads, known technological links with the other major historical goldfields and a comprehensive technical literature, the stamp mill is an ideal subject for an archaeological investigation into the spread of nineteenth century technology into New Zealand.

Research Framework

This research considers the archaeological record of the stamp mill in New Zealand from the time it first appeared here in 1861 up until the last commercial mills closed in the 1950s. One hundred sites and machines are considered (see Appendix A for the full historical accounts and site descriptions) in order to examine both the technology and anthropology of the stamp mill.
The technological study is intended to accurately describe the engineering of the New Zealand stamp mill, and then consider how that technology developed, how and why it came to New Zealand, to what extent it was adopted and adapted here, and whether any innovation occurred here. This study is based on a study of contemporary engineering and industry texts from around the world (Chapters 5 and 6), which are then compared to the archaeological record (Chapters 8 and 9). The use of original texts ensures that the correct technical terminology is adopted and used consistently, and that the operation of the machine is understood from the perspective of the men who designed and used it.

The results of this study are then considered within a framework informed by various global historical archaeological theories, in particular the concept of Technological Dependency (Chapter 10). The intention is to determine whether New Zealand was technologically dependent on other parts of the world, or whether some degree of independent selection or innovation was occurred here.

The focus in the last section (Chapter 11) of the thesis then shifts to consider the stamp mill as a workplace, taking up Mortimer Wheeler’s challenge that archaeology should be about people rather than things. The 19th century mining industry was known to have been hard and dangerous, but there are few first-hand accounts of working in stamp mills in this period. An archaeological approach has the potential to quantify some aspects of this experience. Some of the detailed archaeological engineering descriptions from the technical section, combined with observations from the few reconstructed and operational mills in the country, are used in an attempt to describe the mill as a workplace for people.

The overall aims of this thesis are therefore very simple; it attempts to describe the background of the stamp mill, how it came to New Zealand, what forms it took here, and some of the experiences of the men who worked in it. The overarching theoretical framework considers New Zealand’s place in the global industrial world of the late nineteenth century.

**Questions Not Answered**

Nineteenth century gold mining is a vast subject, from both historical and archaeological perspectives, and some boundaries have to be placed on any study. This research is the first attempt to describe in detail the archaeology of the stamp mill throughout New Zealand, and has generated a large amount of empirical description (Appendices A & B). The decision to assess this information against the contemporary technical literature was very deliberate, as it allows the engineering to be correctly described and understood, which is essential for the research to be valid. No attempt was made to compare the archaeological record in New Zealand with that in Australia and America, but this would be the obvious next step in any similar research.

In addition, the stamp mill was considered largely as a stand-alone site, whereas in reality any mill will be part of an archaeological landscape consisting of the mine, infrastructure and workers’ huts, all within an environmental and geological setting. Again, any future research can build on the information presented here to either expand on a particular site, or consider all sites in a wider context.

This thesis is therefore presented as a (hopefully) comprehensive piece of research, and also as a starting point for future studies.
Thesis Structure

This thesis is structured in a straightforward way, with three main sections. The first section (Chapters 1 to 6) covers the background theory, history and technology; the second section (Chapters 7 to 9) describes the archaeological record; and the third section (Chapters 10 to 12) provides a synthesis. An appendix contains the detailed historical accounts and full description of the archaeological sites upon which this study is based.

Part 1: Background Chapter 2 creates the broad background for this research by considering the events of the Industrial Revolution and the growth and practice of Industrial Archaeology, followed by a discussion of theoretical approaches and a review of the relevant historical, technical and archaeological literature. Chapter 3 considers the background technology by discussing gold mining and the theory, operation and development of the stamp mill up to the point when it emerged as the ‘Californian Stamp Mill’ and travelled around the world in the 1850s and 1860s. Chapter 4 is a brief account of the various nineteenth century goldfields in which the stamp mill was used, including New Zealand. Chapters 5 and 6 then provide a detailed description of the engineering and practice of stamp mills (Chapter 5) and the associated milling circuit (Chapter 6) based on contemporary technical literature.

Part 2: Archaeology Chapter 7 describes the archaeological survey that was undertaken to record New Zealand stamp mills, and discusses various biases in this record that might affect any interpretation. Chapters 8 and 9 then go on to describe the surviving stamp mills in terms of their component parts, following the same format as Chapters 5 and 6, allowing the engineering and archaeological descriptions to be directly compared.

Part 3: Synthesis Chapter 10 provides a synthesis of the technological study of the stamp mill. A series of cases studies are used to consider the mills as complete entities rather than component parts, using the concepts of macro- and micro-innovation to examine how the mill varied from site to site and chronologically. The various influences and agents that affected the mills are then considered, followed by a discussion of the New Zealand stamp mill within an international context (informed by some of the theoretical approaches introduced in Chapter 2). This considers in particular whether New Zealand was dependent entirely on imported technology, or whether a more complex relationship existed. Chapter 11 then moves away from a conventional discussion of technology and development, and attempts to consider the stamp mill from an anthropological perspective, as a workplace for people. The archaeological evidence presented in Chapters 8 and 9 is used in an attempt to quantify some of the working experiences and conditions of the nineteenth century millmen. Chapter 12 concludes this research, and considers how a very detailed engineering approach can be used to address global and local, and technological and human, questions in Industrial Archaeology.
Chapter 2

Industrial Archaeology, Theoretical Approaches, Literature Review

This chapter explores the background ideas and theoretical approaches upon which this thesis is based, reviews the various written sources that are used, and looks at some of the research that has been carried out to date in the field of gold mining archaeology. This thesis is framed within the general field of Industrial Archaeology, but although this is in some ways a simply-defined and easily understood discipline, it has been the subject of much debate since its inception in the 1950s, to the point where the debate is often more involved and complex than the actual practice.

This chapter is divided into three sections. The first section is a review of the history, theory and practice of Industrial Archaeology; the second section is the construction of a theoretical model to be applied in this thesis; and the third section is a review of the various relevant literatures regarding gold mining technology. The plural ‘literatures’ is used deliberately, because this thesis returns strongly to primary sources for not just historical content, but also engineering content, and therefore three distinct sets of literature are considered; contemporary narrative material (ie primary historic sources regarding events, company histories etc); contemporary engineering material (engineering texts and journals); and modern historical and archaeological material. The combination of contemporary technical understanding and modern archaeological method is a critical aspect of this research.

Industrial Revolution to Industrial Archaeology

Before exploring the subject of Industrial Archaeology, the Industrial Revolution in Britain is worth considering briefly as it is generally agreed that Industrial Archaeology grew from an interest in, and concern for, the physical remnants of this transformation (Bracegirdle 1973; Cossons 1993, 2007; Hudson 1965; Labadi 2001; Raistrick 1973). The concept of the ‘Industrial Revolution’ that still endures today was first popularised by Arnold Toynbee’s 1884 book Lectures on the Industrial Revolution in England, while T.S. Ashton’s The Industrial Revolution, 1760-1830 gave it the classic date range that is often quoted (Pryor 2011: 13). The evolution of the steam engine (there was never any single ‘invention’) is often seen as the defining feature of the Industrial Revolution (Figure 2), although Abraham Darby’s use of coke rather than charcoal to smelt iron ore in 1709 and the introduction of the factory system of production by Richard Arkwright in 1771, are also considered significant (Gimpel 1992: 81; Labadi 2001: 78). With regard to steam power, it is important to note that it is not just modern eyes that see the steam engine as a critical development. In 1778 William Pryce (1778: 307-313) stated that Watt’s improvement to the “fire engine” was “an invention of more consequence to the mining interest in Great-Britain than any discovery that has been made for half a century” (Pryce 1778: Preface), making it clear that he thought a major change had arrived.

While it remains a useful everyday concept, the Industrial Revolution has long been the subject of academic debate. The ‘classical’ dates and simple definition have been questioned in many ways since they appeared on print, and even the concept of a ‘revolution,’ has also been challenged.
Some authors argue for a ‘short’ Revolution that should be dated to the early nineteenth century rather than the mid-eighteenth century (eg Belich 2009: 52). Rather than taking the date of Watt’s improvements to the steam engine as the starting point of the Industrial Revolution, this school of thought sees the time the use of the steam engine really began to have an effect as the start of the revolution: “in history, as against technological granny-hunting, the time of mass advent, the beginning of a revolutionary effect, counts more than the time of invention” (Belich 2009: 53). This approach suggests that the true effects of the Industrial Revolution were not felt in Britain until the 1820s, when the bulk of the population’s lives began to change dramatically due to the industrialisation of the country.

A greater number of researchers have argued for a longer rather than a shorter Industrial Revolution, and consider that it was not a single brief event but part of a much longer process (an evolution rather than a revolution) (Martin 2009: 285; Symonds 2003). Many industries in Britain were already mature by 1760, with histories stretching back two centuries or more (Pryor 2011: 14, 152). As early as the 1930s Lewis Mumford stated this case, arguing that development of the ‘machine’ can actually be traced back to the tenth century in Western civilization, and that the Industrial Revolution was “a transformation that took place in the course of a much longer march” (Mumford 1934: 4). Prior to the Second World War this concept gained little traction, as the Middle Ages were considered to have been a period of scientific and technological stagnation, but by the second half of the twentieth century the concept of a ‘Medieval Industrial Revolution’ had been introduced and debated (Carus-Wilson 1941; Gimpel 1992; Lucas 2005: 1-5). Carus-Wilson (1941) specifically referred to an ‘industrial revolution in the thirteenth century’ with regard to the English cloth-fulling industry, where the application of both mechanisation (fulling hammers) and non-human power (the water wheel) transformed the industry.

Other researchers have argued for a yet longer timespan of industrial development. Lucas (2005) was of the opinion that there was growing evidence that European industrial growth had clear precedents in earlier civilisations. Attitudes towards ancient technology underwent a revision in the late twentieth century, especially with regard to the Roman world. The ancient world had been regarded by many scholars as relatively stagnant because of several social factors, including the widespread use of slave labour, the ‘aristocratic’ tradition that discouraged capital investment in industry, and ‘banausic’ attitudes whereby intellectuals despised applied science (Childe 1942: 242; Del Mar 1912: 1; Stowes 1957: 241). More recent research has revised this position extensively, particularly with regard to the use of water power. Estimates of the date of the introduction of water-powered grain mills have been
pushed back to the 3rd century BC, and the widespread industrial use of mills, trip hammers and other mechanical developments by the 1st century AD has been demonstrated (Burnham 1997; Lucas 2005: 8-9; Wilson 2002). Research on Greenland ice cores has shown that levels of air pollution due to metal smelting in the Roman period indicate that the levels of industrial development from the 1st century BC to the 2nd century AD were not paralleled again until the Industrial Revolution (Wilson 2002: 24-27; Rosman et al 1997).

Any discussion of ancient industrial development must also take note of China. The Chinese were using water wheels without gearing to operate trip hammers for rice hulling and to work bellows from possibly as early as the 1st century BC, and certainly by the 1st century AD (Lucas 2005: 9; Needham 1965: 370). It remains unclear to what degree Chinese technology influenced medieval Europe, although Islamic and Byzantine trade routes certainly linked to the two areas and did act as conduits of some innovations (Lucas 2005: 10; Gimpel (1992: 14).

It is not intended to here add to the debate regarding the Industrial Revolution, but it has become clear that substantial technological development had happened centuries earlier than has often been acknowledged, with important developments having been made as early as the 3rd century BC. However, having said that, the Industrial Revolution of 1760-1830, despite all of this questioning, still stands as a useful concept, as the rate of industrial change and development accelerated markedly in that period, and the modern world began to emerge. Cossens (2007: 6-8) is of the opinion that despite the arguments of the ‘gradualists,’ the Industrial Revolution was a period of fundamental change.

This debate about date and scope is not just relevant to a discussion about Industrial Archaeology, but is also to the discussion regarding the development of the stamp mill in Chapter 3. Rather than being an invention of any one time, the stamp mill was the product of a long evolution over 2000+ years, with some particular periods of more rapid technological development. This sits well with the longer and more complex models of industrial/technological development that have emerged in the wider literature.

**Industrial Archaeology**

Industrial Archaeology (IA) has been recently defined as “the systematic study of structures and artefacts as a means of enlarging our understanding of the industrial past” (Palmer & Neaverson 1998: 1). But in the same way that the Industrial Revolution has been the subject of much debate both in terms of its period and its meaning, the definition, purpose and practice of its archaeological offspring, Industrial Archaeology, has also been debated at length.

The very first use of the term is believed to have been in 1896 in an article entitled ‘Archaeologia Industrial Portuguesa os Moinhos’ by Da Sousa Viterbo in the Portuguese journal *O Archeologo Portugues* (Labadi 2001: 78). Little seems to have come of the concept until the 1950s when it was suggested as a possible area of interest by Donald Dudley of the University of Birmingham and then used in an article by Michael Rix entitled ‘Industrial Archaeology’ published in the *Amateur Historian* in 1955 (Hudson 1965: 11; Orange 2008: 84). This was a time when there was a growing interest in Britain’s industrial heritage that was under threat from a combination of general decline and post-war redevelopment. IA gelled as a discipline in 1962 with the opposition to the demolition of the Euston Arch (Figure
3), the 1835 Doric portico at Euston Station in London (Buchanan 1972: 23; 2005: 19; Clark 1987: 170; Orange 2008: 84). While this opposition was unsuccessful as the Arch was demolished, it did draw together many interested parties from a wide range of backgrounds, with the result that the support for and interest in Industrial Archaeology was probably more broadly based than any other branch of archaeology (Cossens 1993: 17; Pryor 2011: 9). The first textbook on the subject (Industrial Archaeology: An Introduction by Kenneth Hudson) was published in 1963, amateur groups were established all over Britain, a National Register of Industrial Monuments was established, and the BBC broadcast a television series entitled Industrial Archaeology (Cossens 2007: 13; Hudson 1979: 2).

Figure 3. The ‘Euston Arch’ at Euston Station in London (Hudson 1965).

Since the birth of the subject, the debates have tended to revolve around a number of specific issues, all of which are interlinked:

- The provision of a simple and workable definition.
- The time period covered, and particularly whether IA is specific to the Industrial revolution.
- The nature of the sites that are covered.
- Whether IA is a period or a thematic study.
- Whether IA is a recording and heritage management discipline, or an academic discipline.
- The credibility of IA as an academic discipline.
- The role of IA in considering wider social issues associated with industrial development.

The critical and overarching issues amongst these are Industrial Archaeology’s role as an academic discipline, and its ability to address social or anthropological questions in addition to its inevitable technological focus.

Definitions of Industrial Archaeology have been offered by almost every author that has written on the subject, and while all in some way consider the two concepts of archaeology
and industry, how they fit together has been widely debated. This has been exacerbated by the interdisciplinary nature of the subject, which can use the skills of the engineer, draughtsman, metallurgist and historian as well as the more traditional archaeologist. Rix initially provided an implied rather than stated definition that he later put more succinctly: “industrial archaeology is the study of the early remains produced by the industrial revolution” (Rix, quoted in Hudson 1965: 12). Debate about this and similar definitions began almost immediately, and has continued to the present day.

An early debate centred around the physical objects or sites that were to be studied. Rix’s definition stated ‘early remains,’ but a number of early official bodies (notably the Inspectorate of Ancient Monuments and the Council for British Archaeology) adopted definitions that centred around ‘industrial monuments,’ which were considered to be buildings or other fixed structures (Hudson 1965: 18-19). To counter this Hudson (1965: 21) proposed a definition that was deliberately not overly rigid: ‘Industrial Archaeology is the organised, disciplined study of the physical remains of yesterday’s industries.’ This avoided both the strict time constraints of the Industrial Revolution and the potentially problematic focus on ‘monuments’ (only large and important things?) while emphasising the ‘physical remains’ that are central to any archaeological approach. This definition was further broadened by Buchanan (1972: 20), who while retaining the reference to ‘industrial monuments,’ stated that they should also be assessed in ‘the context of social and technological history.’

Another early objection was an age-based argument that saw industrial subjects as being too ‘new’ to be studied archaeologically, but this was smartly countered by a number of commentators who not only observed that ‘archaeology’ was concerned with all past phases of human culture, of which technology was a vital component, but also that industry was by no means new and that there was ample evidence of Roman and prehistoric industrial activity (Crawford 1960: 15, 18; Hudson 1975: 11-14; Rasitrick 1973: 5). More enduring (but closely related) has been discussion about the focus on the period of the Industrial Revolution. Raistrick (1973: 3) took particular umbrage at what he viewed as the “menacing and exclusive weight” of the Industrial Revolution, and together with many other authors before and since argued for a much wider and chronologically longer coverage; “industry has an evolutionary history which progresses step by step with the evolution of societies and civilizations” (Crawford 1960:18; Hudson 1965: 12, 14; Labadi 2001: 79; Raistrick 1973: 14). These authors recognised from the outset that all periods could be the legitimate subject of an archaeological approach. Even the early remains of the nuclear age have been proposed as an appropriate subject for archaeological study, some sites of which were brand new when Industrial Archaeology was born (Johnson & Beck 1995). However, despite this widening of scope, the Industrial Revolution remains a strong focus in British Industrial Archaeology up to the present day (Cossons 2007; Nevell 2006).

The debate about the dominance of the Industrial Revolution is an important aspect of another long-standing issue: whether IA is a thematic study or a period study (Martin 2009: 292; Orange 2008: 84; Palmer 1990). It must be remembered that all British arguments have been held in the context of a strong tradition of period-based archaeologies such as ‘Roman’ and ‘medieval’ archaeology. Raistrick (1973: 1-14) argued for a thematic study (that of industry), but freed from the constraints of special reference to the Industrial Revolution. He was insistent that Industrial Archaeology by “subject and emphasis” extended through “all the sub-divisions of archaeology” (Raistrick 1973: 13). Buchanan (1972: 20-21) argued for essentially a thematic approach, but made the observation that in practice it was useful to confine the study to the past 200 years or so as earlier periods were dealt with by more
conventional archaeologist and because of the sheer mass of material dating from the Industrial Revolution. A thematic approach was apparent in most published Industrial Archaeology of the twentieth century. It is notable that even Bracegirdle’s (1973) edited work ‘The Archaeology of the Industrial Revolution’ by its title implied a period approach, but included a chapter on the electricity industry, which entirely post-dates the classic period of the Industrial Revolution.

Other authors have argued for a more strictly period-based approach, focused on the relatively recent period when society had been heavily influenced by industrialisation. Many alternative names that have been suggested for the discipline illustrate this, such as ‘post-medieval archaeology,’ ‘the archaeology of the industrial and modern period,’ and historic-period archaeology (see Palmer 2005: 11). One of the features of this debate is that the word ‘Industrial’ has itself long been problematic for many commentators, and a period definition of the discipline would allow it to be dropped and replaced, an argument that is closely allied to debates about the research focus and academic credibility of Industrial Archaeology (discussed further below). In his recent general work on the archaeology of ‘modern’ Britain Pryor (2011: 10, 14) is of the opinion that “the era of industrial expansion was as much about social change as technology” and that the ‘industrial’ will slip from general use when considering Industrial Archaeology. In the English-speaking New World (in particular the USA, Australia and New Zealand) the period-defined ‘Historical Archaeology’ has long had widespread academic support, and much that would be considered Industrial Archaeology in Britain has instead been considered as Historical Archaeology (Hooker & Ritchie 1989: 7; Palmer 2005: 12). In the New World Historical Archaeology is a reasonably straightforward concept, generally covering the period since European contact with the indigenous cultures. In the Old World, including Britain, it is more problematic as written records can date as far back as the classical period. Palmer (2005: 13) has suggested a compromise whereby a term such as ‘later historical archaeology’ could be used for the academic study of the archaeology of industrialisation, while the old title ‘Industrial Archaeology’ would continue for the popularly understood recording, management and study of industrial monuments and sites.

An early debate in America erupted in 1968 when Vincent Foley (1968, 1969) wrote that Industrial Archaeology was not true archaeology, as amongst other concerns its practitioners were often not professionals and did not dig for their information, and that if industrial sites were considered it should be under the aegis of ‘Historical Archaeology-Industrial.’ He also could not “accept the premise that preservation of a site is within the essential context of archaeology” (Foley 1968: 67). These objections were smartly countered by Robert Vogel (1969), who contested that IA is a broad-based discipline, that it is not necessary to dig to examine the physical evidence of the past, and that archaeologists frequently advise on site preservation. Foley’s arguments have all proven to be correct.

This in turn leads into another debate that dates back to the early days of the discipline; whether IA is concerned with the recording, preservation and management of industrial sites (ie, a practical heritage management discipline), or is concerned with academic research and study into industrial subjects (ie, an academic discipline) (Foley 1968: 67; Orange 2008: 83; Palmer 1990: 275; Palmer 2005: 11; Vogel 1969). IA’s role as a recording and preservation discipline was inevitable given the circumstances of its birth, and today many historic industrial sites remain at threat, meaning that this role is still current and pertinent (Cossons 2007; Palmer 2005: 16). Heritage planning legislation such as PPG-15 and PPG-16 in Britain (now replaced by the National Planning Policy Framework) and the Historic Places Act 1993 in New Zealand have ensured that many archaeological sites, including industrial sites, have
at least been excavated and recorded prior to destruction. There is a strong case for arguing that while threats remain, empirical recording of sites is vital, although some overall strategic direction in this is necessary. Recently there have been efforts to develop research frameworks that provide this direction and purpose for IA work carried out within the general heritage management field (Cossons 2007: 15; Palmer 2005).

Away from the immediate concerns of heritage management, the academic status of IA has been debated at length, and amongst the many issues two main (but related) themes can be teased out: a lack of attention to the wider social issues associated with industry and industrialisation; and the absence of any theoretical framework for research.

One of the recent criticisms of British IA has been its traditional focus on machines and industrial buildings, with less attention paid to social issues and the housing and experience of the workers that filled the factories (Pryor 2011: 8; Symonds 2003). However, this is by no means a new debate, and some early writers specifically considered these social issues; for example Butt & Donnachie (1979: 226-249) devoted a chapter to ‘social archaeology’ that considered workers housing, settlements and institutions such as workhouses. Raistrick (1973: 12) in his introductory chapter clearly articulated his opinion that IA should be “one of the humanities and it must achieve a view of man at work in varying tasks and surroundings, in which view the recording of a factory is as much a recording of the place in which lives have been spent as one which sheltered archaic machines.” Of course, articulating the issues and actually addressing them are different things, and it is undeniable that many published works that have self-identified as IA have overwhelmingly described industrial sites and plant in industrial and/or geographical contexts, but not social or human contexts (e.g. Bracegirdle 1973; Cossons 1993; Haselfoot 1978; Hudson 1971; Smith 1965).

To counter such criticisms, Palmer (2005: 10) has recently suggested that Industrial Archaeology needs to integrate with mainstream archaeology by limiting the tendency to interpret evidence in terms of technological paradigms while ignoring social meaning (see also Cossons 2007: 15). At one level social issues have been addressed by including studies of workers houses and other buildings in wider IA discourses (for example Hughes 2004; Stratton & Trinder 2000: 121-144, and see also Pryor 2011: 14, 15), although as discussed above this has been done in the past. A more sophisticated approach has been the application of theoretical models to IA, thereby not just examining housing and places, but looking for social meaning and experience within the industrial context. Working in Australia, Geraldine Mate (2010: 304) stated; “to have an industrial archaeology without consideration of the social associations is to dismiss the people to focus on the technology alone,” and addressed the issue by concentrating on the social meaning of the industrial archaeological landscape at Mount Shamrock in Queensland.

The absence of theoretical framework has been a regular source of criticism of IA (Palmer 2005: 10; Johnson 1996 quoted in Palmer & Neaverson 1998: 3): “Industrial archaeology has neglected almost all theory in some kind of mistaken belief that it could approach the material remains of industrial society with no particular methodological or explanatory framework” (Grant 1987, quoted in Palmer & Neaverson 1998; 3). Not all authors have been so quick to condemn (e.g Orange 2008: 93), but it is undeniable that IA has strongly empirical roots. However, a slow but steady widening of the scope of IA along a developing path can be traced. After the initial focus on individual sites, a more interpretative approach to IA evolved in the 1970s, and increasing emphasis was placed on the context of sites within specific industries both in Britain and, increasingly, internationally (Bracegirdle 1973; Buchanan...
1972; Hudson 1979; Sande 1976). This was followed in the 1980s by the emergence of a landscape or geographical approach where complete industrial landscapes were considered, such as Trinder’s (1982) *The Making of the Industrial Landscape* and Birmingham, Jack & Jean’s (1979: 8) idea of ‘occupance’ in the Australian industrial landscape. In the same decade American Industrial Archaeology began to diverge from British practice, and was influenced by the structuralist approaches to historical archaeology of Deetz, Leone and Orser (Nevell 2006; Orange 2008: 85), although the more empirical approach as used by the Historic American Engineering Record (HAER) also remained important. In the 1990s a more theoretical approach was also developing in British practice, and a split emerged in British IA. Some practitioners continued with monument-and conservation focused work, and others engaged in socio-economic research (Orange 2008: 85).

In the twenty-first century many of the old divisions remain, and a strong industrial-heritage conservation and recording focus survives and is likely to remain strong in both Britain and America (eg Cossons 2007; Kemp 1996). Publications such as Dibnah & Hall (1999) in Britain and Smith (2001) in New Zealand continue to cater to a popular interest in heritage sites and act as illustrated histories, gazetteers and guides to the ‘enthusiast’ population. In this way they continue a tradition little changed from the 1960s. However, academic approaches to IA have become well developed, and not only produce theoretically informed research, but have also influenced some of the heritage management sector as well. The development of research strategies for IA (Cossons 2007: 15; Palmer 2005) has already been mentioned above. The publication of Palmer and Neaverson’s *Industrial Archaeology, Principles and Practice* (1998) has been seen as an important step in setting out an intellectual and methodological framework for the discipline, and much work has been done on industrial sites with a social focus in Britain, America and Australia (Barker & Cranstone (eds) 2004; Hardesty 2010; Knapp et al 1998; Mate 2010; Nevell 2006; Shackel 2009).

**Industrial Archaeology in New Zealand**

In New Zealand and Australia IA is generally regarded as integral with Historical Archaeology rather than existing as a separate branch of archaeology (Clark 1992: 45; Hooker & Ritchie 1989: 7), although the term ‘Industrial Archaeology’ been used specifically and deliberately on a number of occasions (eg. Birmingham Jack & Jeans 1979; Craig 1988; Hooker & Ritchie 1989; Mate 2010; Petchey 2013; Twohill 1984, 1987; Wilson 1984).

A difference in approach between New Zealand and Britain is inevitable because of New Zealand’s individual history. The key events of European contact with, and settlement of, New Zealand coincided almost exactly with the ‘classic’ period of the Industrial Revolution in Britain (*ca*1760-1830); James Cook first saw the east coast of the North Island in 1769, and the signing of the Treaty of Waitangi in 1840 signalled the beginning of formal colonisation. A period definition of IA in New Zealand would therefore clearly not be appropriate, as it would encompass all of New Zealand’s European history which, although arguably closely tied to industrialising Britain, was by no means solely ‘industrial.’ Conversely, ‘Historical Archaeology’ is appropriate, as it neatly encompasses the period for which written records first become available. ‘Industrial Archaeology’ can therefore only have a thematic definition in New Zealand, but in a similar way to which it failed to gain academic credibility in Britain for a long period, it has not gained an academic foothold in New Zealand.
Attempts to define IA in the New Zealand literature have generally simply reviewed the British definitions (eg McKinlay 1984: 57), and published works, notably Geoffrey Thornton’s (1982) *New Zealand’s Industrial Heritage*, resemble much of the early British literature in the use of a thematic industry-by-industry approach accompanied by narrative histories and site photographs. The evolution in academic attitudes towards British and American IA was reflected in similar attitudes in New Zealand. In 1984 Twohill (p. 3-4) commented that Thornton’s work was a “point of departure in the development in New Zealand Industrial Archaeology” as it was the first attempt to place industrial sites in a theoretical context. Hooker & Ritchie (1898: 5) were more critical, regarding it as a well-presented series of essays on historical industrial development, but considered an archaeological approach as conspicuous by its absence. Smith (1990: 86) made a similar point, dismissing much of what had purported to be IA up to that date as being more properly considered industrial history. This reflects the comment made by Minchinton (1983: 125) about IA worldwide, that some works were little more than an economic or technical history of an industry together with a gazetteer of sites.

The 1980s probably saw the most widespread use of the term ‘Industrial Archaeology’ in New Zealand (eg Broad et al 1984; Twohill 1984), but from the 1990s its use declined, albeit with a number of exceptions (Jones 2007; Mitchell 2012; Petchey 1996; Ritchie 1990). Its usage appears to largely come down to personal preference. In *Archaeological Site Recording in New Zealand*, Prickett (1999: pp. 75, 80) used ‘Industrial Archaeology’ only when discussing British Practice, and in the local context referred to ‘industrial sites’ within a clear historical archaeology framework, while Jones (2007) in the *Penguin Field Guide to New Zealand Archaeology* made specific use of the term in a number of places (pp. 51, 129, 170, 215, 244). The decline in the use of the term seemed to lead to (or at least be concomitant with) the local dropping of the debate about the role and purpose of IA, and the lengthy debates that occurred in Britain and America largely passed New Zealand by.

Nevertheless, a great deal of work was carried out on industrial sites in the 1990s and 2000s. As has already been stated above, much archaeological work carried out in New Zealand in the past 20 years has been under the aegis of the *Historic Places Act 1993* (that replaced a broadly similar 1980 Act), that requires archaeological assessments, surveys and sometimes excavations prior to development work. This has been carried out on a site-by-site basis with little overarching research framework, but a large number of industrial sites have been investigated (eg Dodd & Richardson 2012; Hamel 1991; McGovern-Wilson 2001; Petchey 1994, 2005). A second major block of work has been carried out for the Department of Conservation. This has produced a series of reports on historic and industrial sites on the conservation estate, which largely consist of evidence of extractive industries such as gold mining and saw milling. Much of this work has been research-based but with potential for informing site management and conservation issues (Hamel 2001; Petchey 2002, 2006a, 2006b; Prickett 2002; Ritchie 1990; Smith 2002; Watson 2007).

In the field of academic research, industrial subjects have continued to be studied within an historical archaeological context (eg Clough 1990; Macready et al 2013; Moore & Ritchie 1998; Palmer 2000; Smith & Prickett 2004), although the teaching of historical archaeology in New Zealand universities is currently (2013) limited to one academic position (Ian Smith at Otago University), inevitably restricting the potential research output. The term ‘Industrial Archaeology’ has also reappeared, and recent work by Mitchell (2012) considered workers housing within an Industrial Archaeological context, continuing the earlier paradigm of considering social issues by examining workers houses and settlements. The journal
Australasian Historical Archaeology (formerly The Australian Journal of Historical Archaeology) continues to carry many papers on industrial sites and subjects, including some New Zealand sites (eg. Carpenter 2012; Moore & Ritchie 1998), while the Journal of Australasian Mining History is devoted to the history and archaeology of the mining industry in this region, although most papers to date consider Australian sites.

Building a Theoretical Model

One of the most notable aspects of gold mining archaeology of the nineteenth century is the international nature of the industry and its technology, which many authors have commented on (eg Burt 2000; Menghetti 2005; Moore & Ritchie 1998; Petchey 2013). It is reasonable therefore to consider theoretical approaches in historical archaeology that consider the global context, in particular the concepts of ‘Modern-World Archaeology’ and ‘Global Historical Archaeology’ that have been discussed at length by Charles Orser, and which evolved in part from Wallerstein’s ‘World-Systems Theory’ (Orser 2008, 2009a, 2009b). These models use a multi-scalar approach, and consider archaeological evidence in multiple contexts at both global and local levels; the combination sometimes being referred to as ‘glocalisation.’ World-Systems Theory is particularly associated with the global capitalist system, and uses the concepts of ‘core’ and ‘periphery’ to examine the inequalities inherent in this system, and as such is well suited to the study of the intensely capitalist gold mining industry. The related Network Theory, with its focus on connections between socio-spatial entities (comprising networks made up of nodes and linkages that extend through both space and time) allows consideration of complex human interactions to also be considered, and increases the utility of these approaches to the complexities of the archaeological record (Orser 2009b: 263-264).

Elements of these theories are used in this thesis; specifically the overarching concept that the New Zealand archaeological record must be interpreted in both local and global contexts, and that these change through time. The concept of cores and peripheries is utilised, and the associated Dependency Theory is explored in some detail (see further discussion below).

While these models provide an overarching global framework, other approaches borrowed from the disciplines of economic history and archaeology are used to study in detail (ie at the local scale of the ‘glocalisation’ model) two different aspects of the archaeology of stamp mills in New Zealand; the technology used the mills in terms of design innovation and technology transfer (a technological approach); and the role and experiences of the people that worked in the mills (an anthropological approach). The two are linked by the concepts of ‘sociotechnical systems’ (Hughes 1983, see below), and ‘Agency’ whereby individuals can act independently and deliberately. Using the methods described below, the intention here is to use the technological approach to inform the anthropological, and ultimately describe the New Zealand stamp mill at both the international technological and individual human scales.

Technology

Much has been written about the nature and process of technological invention, innovation, adaptation and transmission in the world’s goldfields from economic and technological history perspectives (eg Burt 2000; Davey 1996; Jack 1984; Limbaugh 1998; Menghetti 2005; Newell 1985, 1986; Todd 2009), and some of this work has been informed or supported by archaeological research (eg Landon & Tumberg 1996; Moore & Ritchie 1998). The processes of change, the machines and techniques that resulted from those processes, and seeking explanations for these processes are central to these discussions. A critical
technological history study was Hughes' (1983) consideration of the development of electrical systems in America, London and Berlin, in which he identified the importance of social and political systems to the successful transfer of technology; a sociotechnical system of enormous complexity with many different agents and influences.

Two approaches from the technological history literature are used here, one to describe the process of technological change (‘macro-innovation’ and ‘micro-innovation’), and the other to examine this process in terms of the global context of the New Zealand goldfields (‘technological dependence’ vs ‘technological sovereignty’).

**Macro- and Micro-Innovation**

Mokyr (1990: 13) and Burt (2000: 324) have discussed the concepts of micro- and macro-innovations that are derived from evolutionary theory; micro-innovations are the small, incremental steps that improve existing techniques or machines; while macro-innovations are those that embody radical new concepts without clear precedent. By identifying and then tracing such developments in the historical and/or archaeological records of a goldfield it is possible to examine the technological development of that goldfield and its links with other similar fields nationally and internationally. The economic historians referenced above have done this by examining the development and adoption of such technologies as the stamp mill, hydraulic sluicing and the cyanide process of gold extraction (see especially Burt 2000). Influences such as pragmatism, environmental constraints, frontier constraints and cultural eclecticism have all been identified, with a general consensus that pragmatic adaption (or micro-innovation) was widespread and typical of the frontier goldfields, while new innovation (macro-innovation) was much rarer and (with a few significant exceptions) often originated in the older mining areas of Britain and Europe where the economic pressures from declining ore bodies and competition from the richer and more easily worked New World mines, combined with the rise of professional and scientifically-based engineering, led to the development of new technologies.

**Dependency Theory vs. Technological Sovereignty**

Even basic study of the New Zealand goldfields shows that international technology was the mainstay of the industry, which would at first glance appear to support the idea that New Zealand was technologically dependent on imported designs. Dependency Theory sees modernisation or technical development as an inherently unequal process, where production and capital emanate from core areas to dependent peripheral areas (Orser 2009b: 254, 255). The concentrated supply of inputs from a single source is a major indicator of dependency, with this dependency being manipulated or exploited by the external source (Todd 2009: 8-9, 235). Technology is imported, primary products exported, and local innovation and development is inhibited. In the mining field this would involve the importation of mining technology and machinery, and the export of gold, to the ultimate advantage of the more developed partner. Dependency Theory has been rejected by some postmodern researchers who feel that culture can not be explained by large-scale grand theories (see Orser 2009b: 254), but it is still is useful when considering nineteenth century mining technology, because the capitalist system with its technological cores and peripheral areas are very clearly defined within this context. Burt (2000: 347) has argued that the American nonferrous mining industry was technologically dependent on Europe until the end of the nineteenth century, and
states that the archaeological evidence of American mining is indistinguishable from that in many other parts of the world (his point is expanded on in Chapter 10 below).

A specific counter to Dependency Theory is the concept of Technological Sovereignty. Todd (2009: 247) and Menghetti (2005: 218) writing on historic gold mining in Australia have also found that the technology was international, but have raised the concept of “Australian technological sovereignty” rather than technological dependency, whereby informed decisions were made to seek out international technology, after which it was adapted to suit local requirements. Todd (2009: 235) points out that technological sovereignty is not the same as technological independence, whereby new technology is locally generated, although the two can go together. A key aspect of testing this model using the archaeological record should therefore be the presence of international technology selected and adapted locally to address local problems. A mixture of both international and local agents should be present, and the influence of local factors (topography, geology, climate etc) should be discernable.

**Testing the Theories Archaeologically**

The macro- and micro-innovation model is ideally suited for archaeological testing of the dependency/sovereignty model, as it breaks technology (stamp milling in this case) down into logical and discrete evolutionary steps that can be observed in the field, and which can then be examined in order to determine when, where, how and why various changes and developments happened, and how successful and enduring these changes were. This information can then be used to test whether technology was simply imposed from outside, or whether various local factors influenced both the selection and further adaptation of the technology, and therefore whether a dependency or sovereignty (or any other processes) explanation is appropriate.

The Californian stamp mill has been identified by numerous authors as a significant micro-innovation that coalesced in California in the 1850s (eg Burt 2000: 326; Limbaugh 1998: 41), and this interpretation provides a starting point for the archaeological study of these mills in this thesis (see the discussion in Chapter 5 below). The process of change and innovation did not cease once the Californian Mill emerged, but rather the machine continued to be modified and altered to suit varying local conditions and requirements in the different goldfields and countries in which it was adopted; the process of micro-innovation. By examining the archaeological remains of surviving mills in New Zealand it is possible to identify various design features and modifications, and examine how the technology was adopted and adapted. This approach takes the concept of micro-innovation and applies it at its finest level; the level of incremental change and modification within a single type of machine. Also considered are the other processes carried out in association with a stamper battery, including ore dressing, amalgamation and cyanidation, all of which obey the same rules of macro- and micro-innovation.

By comparing this archaeological evidence with contemporary engineering and technical literature, which was itself derived from the goldfields and presents what was at the time seen as best practice, New Zealand’s place in the international goldfields can be examined. This very detailed engineering approach used in an archaeological context has been termed the ‘Archaeology of the Machine.’
**The Archaeology of the Machine**

The Archaeology of the Machine uses a detailed and forensic approach to industrial sites and artefacts in order to examine their use and history from an archaeological perspective. This differs from earlier detailed recording of machinery and industrial sites in that not only does it address the operation of the machine (a technological outcome), but it can also examine the role of the people that built, operated and maintained the machine (an anthropological outcome). In Britain Cossons (2007: 16) has termed this the ‘archaeology of engineering’ and the ‘archaeology of machines,’ while in America Gordon & Malone (1994: 24, 349) have discussed ‘engineering analysis’ within an archaeological context, together with ‘machinery as a research tool.’ One of the most detailed examples of this approach to date is Bailey & Glithero’s (2000) *The Engineering and History of Rocket: A Survey*, which re-examines Stephenson’s *Rocket* in detail in order to elucidate aspects of its design, construction, use and modification over time. Most recently White (2010) has applied an engineering analysis to the Skidoo stamp mill in California, examining the strategies that were used to keep an ageing mill in operation based on the surviving archaeological evidence of that mill.

As already discussed, one on-going criticism of IA has been its focus on machines and industrial buildings, rather than social issues and the experience of the workers that filled the factories (Labadi 2001: 78; Pryor 2011: 8; Symonds 2003). Another criticism has been the lack of attention paid to artefacts, attention instead being paid to sites, structures and landscapes (Palmer & Neaverson 1998: 3-4). By contrast, historical archaeology as practised in America, Australia and New Zealand has developed a strong focus on artefactual analysis, employing functional analytical approaches to consider the use and social context of artefact assemblages (Garland 2012: 63-64). However it can be argued that the machine is nothing other than a very large artefact; or in other words, the machine is material culture. In the same way that the usewear and retouch on a prehistoric lithic blade or the pattern and social meaning of a ceramic plate are considered during archaeological analyses, so the machine can be questioned from an archaeological perspective to inform us about the experiences of the people that have interacted with that machine.

The design of every part of a machine is the product of a deliberate choice by a person in the past, often modified by others as designs are refined and altered (the process of micro-innovation). In many cases patent protection was sought for these changes. Once a piece of equipment is put to work it starts to wear, and may sometimes require replacement or repair. Every component in a machine, and the machine as a totality, therefore represents the decisions, actions and experience of one or more people; it represents human agency. The forensic examination of the machine used to examine its technological aspects therefore also presents the opportunity to examine the experiences of the people involved, and this is done in Chapter 11. The twin aims of this thesis, to examine the technology embodied in the stamp mill to place New Zealand in an international context, and to examine the role and experiences of the people who actually worked with these machines, can therefore be addressed using the data from the same detailed archaeological approach.
Literature Review

As outlined at the beginning of this chapter, the literature upon which this thesis is based can be divided into three broad classes: contemporary narrative material (i.e., primary historic sources regarding events, company histories, etc.); contemporary engineering material (engineering texts and journals); and modern historical and archaeological material.

Contemporary Narrative Literature

This is all of the contemporary material that described general mining trends and specific activities, including annual reports, newspaper reports, and books, other than the highly-technical engineering material that is discussed separately below.

The most important source for New Zealand’s mining history are the annual Mines Reports produced by the Mines Department that were published in the *Appendices to the Journals of the House of Representatives* (AJHR). These cover in detail the period from the 1863 to 1866, and then from 1872 until the 1950s. The gap in the records was due to a dispute between the Provincial Government and the General Government (Wellington) regarding goldfields administration. The annual Mines Reports varied in layout and content somewhat over the years, but in general they contained an overview of mining activity in the country, a series of regional reports from Mines Inspectors and/or Wardens, statistical data on mining, and sometimes detailed descriptions of particular processes or plant. It is often possible to trace a mining company’s history through the annual reports, and careful reading of a number of more modern histories (discussed below) reveals that the AJHR reports are the primary source for much of what has been written about New Zealand’s mining history.

For the earliest period of the gold rushes the *Votes and Proceedings* of the various Provincial Councils contain reports and details on events. The *Votes & Proceedings of the Otago Provincial Council* were extensively used in this thesis for details of the events of 1861 and 1862 as the Otago gold rushes started. The same gap from about 1866 to 1872 that affected the AJHR records also affected the Provincial records.

Fortunately, such gaps can be filled to a certain extent by newspaper research. The recent development of on-line resources such as Paperspast (www.paperspast.natlib.govt.nz) in New Zealand and Trove (www.trove.nla.gov.au) in Australia have made many historical newspapers readily available. Many provincial newspapers were established during the gold rushes, the *Otago Daily Times* being a notable example, and carried regular mining intelligence columns, together with tender calls for development work, notices and accounts of general meetings and narrative accounts of journeys to the various goldfields. However, newspaper research contains many pitfalls, especially the fact that much information was supplied by the mining companies themselves, and so can be misleading with regard to yields, profits, and future prospects.

For a period the New Zealand mining industry had its own monthly journal, *The New Zealand Mines Record* (NZMR). This was published between 1897 and 1909 by the New Zealand Mines Department, with Patrick Galvin as editor. It was thought that there needed to be a source of reliable mining information in an official form, partly because of the fear of

---

1 The Auckland Provincial Council published their proceedings as ‘Journals.’
misleading promotion at the time of a flood of British investment into the New Zealand mining industry (Salmon 1963: 214). The NZMR contained information about mine developments, mining company activity and articles on a variety of mining–related subjects, including some historical retrospectives that are now invaluable as they were written by men who were actually present during the early rushes (eg McCombie 1897).

**Contemporary Technical Literature**

This consists of technical textbooks, journals and catalogues that specifically dealt with the technical and engineering aspects of stamp mills and gold recovery processes. Most of this material was published overseas, particularly in Britain, America and Australia; notably the countries that had large mining industries and the large engineering companies that supplied mining plant. These sources generally post-date ca. 1880 and were often heavily weighted towards large-scale operations (White 2010: 66).

Technical texts that are used extensively in this work include Louis’ *A Handbook of Gold Milling* (two editions, 1894, 1902), Del Mar’s *Stamp Milling, A Treatise on Practical Stamp Milling and Stamp Mill Construction* (1912), Gowland’s *The Metallurgy of the Non-Ferrous Metals* (two editions, 1914, 1930), Richards’ *Ore Dressing* (1903, 1906) and the International Library of Technology’s *Metallurgy of Gold, Silver, Copper, Lead and Zinc* (two volumes, 1902). These, and many other similar texts that were consulted, were intended as technical references for the education and on-going reference of mill engineers and managers, and as such contain the contemporary technical information that is essential to interpret the surviving archaeological evidence of these mills. Many of these works were very well illustrated, and these images are invaluable for archaeological interpretation, as identification of items of machinery in the field relies on visual identification. Chapters 5 and 6 in this thesis utilise many of these images.

Industry journals, such as the *Transactions of the Institution of Mining and Metallurgy* (Britain), the *Transactions of the American Institute of Mining Engineers* (America) and the *Australasian Institute of Mining Engineers* (Australia) all contained contributed papers on a wide variety of mining subjects (not just gold mining). They similarly cover much technical ground, and also have the advantage that sometimes it is possible to follow debates through published comments and replies to papers. This underlines the fact, often forgotten, that the industry was neither static nor evolving in a single uniform direction, but developed as a result of continuous experimentation and debate between different engineers in different regions and countries.

Mining equipment catalogues were issued by engineering or supply companies to advertise the stock that they carried. *The Mine and Smelter Supply Company Catalog No. 22* (1912) is used extensively in this thesis. It does contain some technical detail, but most importantly it is extensively illustrated, and confirms what spare parts were actually available to mill owners.

The main New Zealand-published technical work was H.A. Gordon’s *Miners’ Guide* that went through three editions (Gordon 1889, 1894, 1906). Henry Gordon was until 1896 the Mining Engineer to the Mines Department, and in 1884 was sent by that Department to Australia to report on gold mining techniques (Salmon 1963: 214). He not only published his technical book, intended as a textbook for mine managers, but also co-operated in the production of the 1887 *Handbook of New Zealand Mines* and wrote extensive technical
reports in the annual Mines Reports. He was therefore a direct conduit of information regarding international mining technology to New Zealand mining men.

Modern Historical & Archaeological Literature

As the gold rushes in America, Australia and New Zealand become more distant, and have long since been mythologised, they have attracted a continuing stream of researchers analysing and re-analysing them. In New Zealand this started early with work such as Vincent Pyke’s *History of Early Gold Discoveries in New Zealand* (1962, first published in 1887), and continues to the present day with Eldred-Grigg’s *Diggers Hatters & Whores* (2008). The latter volume runs to 498 pages of narrative on the New Zealand gold rushes, but even this can be little other than a once-over-lightly due to the size and complexity of the subject. Some specific aspects of goldfields history have attracted a great deal of academic attention, one particular area being the role that the mining industry (both gold and coal) played in the industrial relations and union history of New Zealand. As Jack (1984: 33, 37) has observed, the contemporary and subsequent political-historical writing concerned with the Waihi miners’ strike of 1912 is ‘immense.’ In addition, as already discussed above, much has been written from an economic history perspective about the international development and spread of gold mining technology (Burt 2000; Davey 1996; Jack 1984; Limbaugh 1998; Menghetti 2005; Newell 1985, 1986; Todd 2009), and this material is used here both for historical detail and to create a model for the interpretation of archaeological evidence.

Published historical accounts are used here largely to provide historical background and synthesis. These works can be at a national or local scale; Salmon’s *Gold Mining in New Zealand* (1963) covers the entire country and remains a standard reference; Latham’s *The Golden Reefs* (1984) covers one region comprehensively; while McAra’s *Gold Mining at Waihi* (1988) covers the history of one small area in great detail. Many general regional histories contain some chapters on gold mining, such as the series of Otago Centennial Historical Publications. One thing to bear in mind is that the mining information in many general histories can often be traced back to a few primary sources, of which the *Appendices to the Journals of the House of Representatives* is the most common. This raises the spectre that any error in these official records is likely to be repeated *ad infinitum* in subsequent research.

The archaeological literature is more focussed, generally being site specific, or looking at specific site types within a defined geographic area. As has been discussed above, much of this work has been carried out for the Department of Conservation, or its predecessor the New Zealand Forest Service. The resultant reports vary widely in the amount of technical detail presented, which is generally dependent on the knowledge of the archaeologist involved and the scope of the report (ranging from large scale landscape surveys to detailed site descriptions). Examples of detailed work that address technological detail include *The Quartz Mines of the Blackwater Goldfield* by N. Hancox (1985) and Moore & Ritchie’s (1998) discussion of the ore-roasting pits at the Victoria Battery site. Some archaeologists have specialised in mining archaeology, and have produced large bodies of work in specific parts of the country, notably Neville Ritchie (Otago and Coromandel), Ray Hooker (West Coast), Jill Hamel (Otago and Southland) and Petchey (Otago and Southland).

---

2 This work being at least in part based on first hand experiences, as Pyke was the first Commissioner of the Otago Gold Fields Department in 1862.
Most archaeological work on mining sites has involved field survey and recording of above-ground structures. There have been relatively few archaeological excavations of stamp mill sites, notable exceptions being Hamel (1994b) at the Deep Dell Battery and Petechey (2005) at the Golden Bar Battery, both near Macraes Flat in Otago. Both of these investigations were carried out in heritage management contexts, due to the nearby activities of modern gold mine operations. Both also included excavations of workers’ hut sites, meaning that the social aspects of the sites were incorporated.

The greatest value of this archaeological literature, together with the New Zealand Archaeological Association Site Record File (online as Archsite), to this research has been site location information. While the detailed analysis undertaken in this thesis has required new site visits to most relevant sites, the initial location and selection of sites was almost entirely dependent on this earlier body of work.

Outside of New Zealand there has been a great deal of historical and archaeological work done on mining sites, and again the body of literature is vast. This literature was not extensively reviewed for this thesis, as the primary aim was to assess the New Zealand archaeological record against the contemporary engineering literature, and subsequent detailed comparison with the overseas archaeological resource would be a next (and very valuable) step. Probably the most immediately relevant work is that done in Australia, including historical research such as Birrell (1998, 2004), Blainey (1993), Davey (1988) and Menghetti (2005), archaeological research such as Birmingham, Jack & Jeans (1979) and Pearson & McGowan (2000), and work from both disciplines published in the Journal of Australasian Mining History. The American archaeological and historical record is also directly relevant, and again there is a large literature due in no small part to the importance of the gold rushes to west coast American history. The Historic American Engineering Record (HAER) has been making extremely detailed records of surviving mining structures and equipment for many years (for example, see McVarish 2008: 302), and recently Hardesty (2010) and White (2010) have been applying archaeological interpretations to this type of detailed record.
Chapter 3  
Background History & Technology:  
The development and theory of the stamp mill

Introduction

The basic operation of a gravitation stamp mill was very simple. It was a crushing machine that worked by dropping heavy weights on lumps of rock, to reduce them to the consistency of sand. The machine consisted of a series of heavy vertical rods (‘stems’) that were fitted with heavy iron stamp heads, and were raised and dropped onto gold-bearing rock (ore) held within a rectangular iron box (mortar box). The ore was broken up, releasing any gold that it held, which could then be recovered by a number of methods. This basic machine, although considerably refined in the nineteenth century, had been widely used in medieval Europe, and possibly had its origins in Roman mines of the second century AD.

This chapter discusses some of the main concepts concerning stamp milling and its associated processes, including the nature and occurrence of gold, the basic approaches to gold mining and ore processing, and the theory of operation of the stamp mill itself. It then discusses the history and development of the stamp mill up to the point where it emerged as the crusher of choice in the main nineteenth century international goldfields. This provides the background for the following chapters, which describe the main international gold rushes and the detailed engineering design of the late nineteenth and early twentieth century stamp mills.

Basic Concepts

Gold (Au) has a number of physical properties that make it both desirable and relatively easy to find and work. It is one of the few metals that occurs naturally in its metallic state, and as such was one of the (if not the) first metals to be discovered and used by people. It is an attractive yellow colour that does not tarnish, and the metal does not corrode. It is malleable and easily worked, and can be beaten out into extremely thin sheets. It has a high specific gravity (SG=19.3, or 19.3 times heavier than an equivalent volume of water), which makes it comparatively straightforward to separate from other minerals by washing in water (Gowland 1914: 192; Gregory 1980: 34).

Gold is generally found in two contexts: in reef deposits and in alluvial deposits (Healy 1978: 30). Reef deposits are often (but not always) associated with quartz veins or lodes set within natural bedrock, having been deposited in the distant past by hydrothermal activity (Lee & Forsyth 2008:10). The gold is mechanically mixed with the rock (‘ore’ is the term for rock with an economic metal content), and usually not in chemical combination. Alluvial deposits consist of gold that has naturally weathered out of this ore and been sorted by water flow. Because of the very high specific gravity of gold it will sink quickly in a stream of water, whereas lighter minerals will be washed away, and eroding gold is slowly concentrated in streams and rivers (Gregory 1980: 34-35; Healy 1978: 30-33; Lee & Forsyth 2008:10). Eluvial deposits have similarly eroded but have simply been sorted by wind and gravity. The term for naturally eroded and sorted gold concentrations (whether by water or wind) is a ‘placer’ deposit.
These placer deposits were the objects of most of history’s gold rushes, where miners dug out and washed the auriferous (gold-bearing) gravels to recover the gold, using a minimum of capital and equipment as the hard work had already been done by natural processes. The reef deposits were a much more difficult proposition for the miners, as the gold ore not only had to be mined from the surrounding bedrock, it then had to be broken up and the gold separated from the gangue (waste material).

Gold ores can be divided into four main groups (Healy 1978: 35):

- **Gold-quartz**: in which quartz is the main mineral and the gold occurs distributed through it.
- **Gold-sulphides**: in which gold is the only valuable mineral.
- **Gold sulphides**: in which valuable base metal compounds also occur.
- **Gold-tellurides**: Tellurium and possibly selenium are the only elements that combine with gold in nature.

Simple gold-quartz ore was (theoretically) simple to process (often referred to as ‘free-milling’) as the gold could easily be saved once broken free from the ore, but the presence of sulphides, base metal compounds or gold-tellurides could make gold recovery difficult and complex. Such problematic ores were referred to as ‘refractory’ ores, and much time, effort and money was spent trying to develop efficient and effective methods of processing them. Chapter 6 describes some of the plant and processes that were historically used to save gold from refractory ores.

**Gold Mining**

Because gold occurs naturally in its metallic state, little speculation is required as to how it was first found: it would have simply been seen and picked up in a stream or river bank. This is a quite different proposition to the other metals, almost all of which only occur naturally as compounds (with the exception of a small amount of native copper and silver and meteoric iron) that look nothing like metal, and require to be smelted to obtain a metallic state (Forbes 1950: 140). This is by no means an over-simplistic observation, as all of the nineteenth century gold rushes discussed below in Chapter 4 started with the discovery of gold visible to the naked eye. It was only after the easily won shallow gold deposits had become worked out that more advanced mining and processing methods were adopted.

This discovery of gold was made independently in a number of places around the ancient world, and it was widely transported along trade routes. Gold has been recorded in early archaeological contexts in Europe, Africa, South America and Asia, and some of the first Greek gold coins were struck in Lydia in the 7th century BC (Healy 1978: 75). Gold dust and nuggets from surface or shallow deposits were known from Arabia and Paeonia, Strabo and Herodotus both described gold deposits, and Egyptian wall paintings from the XX and XXI dynasty show gold washing (Healy 1978: 76).

In the ancient world most gold was won from alluvial deposits by washing river gravels, by ground-sluicing or by hushing (Healy 1978: 76; Morrell 1968:1-9; Wilson 2002: 17). The processes of ground sluicing (working alluvial deposits using a continual flow of water to break up the ground) and hushing (storing water and letting it run over the ground to be worked in one large release) were extensively developed by the Romans, with archaeological
evidence found of their use in Spain and in Wales in the 1st and 2nd centuries AD (Morrell 1968: 5; Wilson 2002: 17, 19, 29).

As placer and alluvial deposits became depleted, underground workings of deeper veins was undertaken. Strabo made a possible reference to opencast working by the Tarbelli, and underground mining of gold and silver at Siphnos was recorded in the 6th century BC (Healy 1978: 77). The Romans developed underground mining techniques considerably, and established large and extensive mines with Archimedean screws and water wheels to pump dry the deeper levels that often went below ground water levels (Healy 1978: 95).

In medieval Europe, Germany became a leader in mining and metallurgical technology as German silver deposits were discovered and worked, and this expertise spread to other countries as additional silver deposits were found. Analysis of the mining vocabulary used in various parts of Europe has shown that to a substantial degree it is of German origin (Gimpell 1992: 70). As discussed in more detail below, the seminal medieval mining text, Agricola’s De Re Metallica of 1556, was based on observations of the German mining and metallurgical industry, and German expertise was sought in many of the world’s mining areas. Four German miners were engaged in 1303 to prospect for minerals in Wales (albeit unsuccessf

Figure 4. The system of shafts and adit levels in a mine (Gordon 1906).

The actual process of underground mining was at once a simple concept and a complex and difficult process. Once an ore body had been identified the mine would need to be developed by the excavation of shafts and/or drives to enable the reef or lode to be opened up (Figure 4). Historically this tunnelling was all carried out by hand, using simple tools such as picks and hammers, in galleries that were often so small that it was impossible for miners to stand upright as they worked (Healy 1978: 81). The technique of ‘fire setting’ was sometimes used whereby a fire would be built against the face to be mined, and the heat fractured the rock making it easier to excavate (Forbes 1950: 53). It was only with the introduction of black powder for blasting in the seventeenth century, and then powered rock drills in the late nineteenth century, that the mining process became any easier, although it remained no less dangerous. There was always a risk of accidental explosions, while the dust created by the early rock drills caused silicosis (also known as ‘miners phthisis’), a lung condition that could bring about a long and drawn out death (Birrell 1998: 139; Latham 1984: 355-356; McAra 1988: 253).
Once a mine had been opened up, the ore was removed by a process known as ‘stoping,’ whereby the reef or lode would be systematically excavated and the ore taken to the surface for processing (Figure 5). The voids (‘stopes’) left once the ore was removed would often be backfilled with mullock (waste rock of no economic value) (Gordon 1889: 61). Excess mullock would be dumped outside the entrance of the mine to create ‘mullock heaps,’ which are often the most distinctive archaeological features of historic mine sites today.

![Figure 5. The timbering of a stope in a mine (Gordon 1906).](Image)

This simple description belies the heavy and dangerous work that was involved in mining, and the high death rates amongst the miners. As Lewis Mumford (1934: 68) observed: ‘Among the hard and brutal occupations of mankind, the only one that compares to old-fashioned mining is modern trench warfare.’ And it must be remembered that he was writing when the carnage of the First World War was still in peoples’ memories.

**Beneficiation and Ore Processing**

Beneficiation was the process of removing as much gangue from the ore as possible, to maximise its value and minimise the effort and expense of processing it (Gregory 1980: 14, 239). This could be done at a coarse level by hand-picking barren rock from ore, and/or by concentration after the ore had been broken down. The breaking down of ore into small pieces (often to the consistency of sand) was an important part of the gold recovery process, as this freed the gold from the rock matrix. Two basic ways of breaking down ore were crushing and grinding, and although the two are often confused, they are quite different operations:

**Crushing** as applied to metallurgy may be defined as the process of breaking down an ore by impact or direct pressure sufficient to cause fracture (Liddel 1926: 59).

**Grinding** is the process of disintegrating an ore by a combination of impact and abrasion (Liddel 1926: 71).

Crushing was generally carried out by the stamp mill, although some early mines may have used trip hammers, and jaw crushers and roller mills were developed in the nineteenth century (see Chapter 6 below). It is important to note that the stamp mill was an impact crusher, and no grinding took place. Although in the California mill the stem was rotated as it was raised (in order to even out wear), and some authors thought that this also imparted a grinding
motion at the time of impact (eg Phillips 1867: 172), it fell straight and therefore had no grinding action.

Grinding was often carried out as a secondary process after crushing had reduced the ore to reasonably sized lumps. Several early grinding mills were used, including the circular millstones similar to those used for flour milling (called a ‘Crazing mill’ in the tin mines of Devon and Cornwall) and the Mexican/Spanish ‘Arastra’ (or ‘Arrastra’) that used heavy stone drags in a circular stone-lined trough (Figure 6) (Hollister 1867: 103; Newman 1998: 40).

**Figure 6. An example of an animal-powered arastra (Gowland 1914).**

**Gold Saving**

Once the ore was reduced to the consistency of sand, the next step was to recover the gold. Gravity separation is the simplest method for the beneficiation of minerals, and was used with little change from ca. 500BC to ca. 1550AD, and is used in a modified way to the present day (Turner 1991: 213). This made use of the high specific gravity of gold, and effectively emulated the natural processes that led to the formation of placer deposits. The crushed ore and water (‘pulp’) would be run over some sort of roughened surface, where the heavier particles (including the gold) would fall and settle, while the lighter material (the gangue) would be washed away. Many forms of surface were used, including sheepskin (Healy 1978: 75) and bunches of twigs (Agricola 1950).

The other main historic method for saving gold was mercury amalgamation. Mercury (often known historically as ‘quicksilver’) is the only metal that is liquid at common temperatures, and it readily forms alloys (known as amalgams) with a number of metals, including potassium, sodium, gold, silver, tin, lead, zinc and bismuth (Gowland 1914: 348). This ready affinity that mercury has for gold means that free metallic gold could be saved by passing pulp over a mercury coated surface or mixing it with mercury in various ways, and then collecting the resultant amalgam from which the gold was easily recovered by heating. This evaporated the mercury, leaving the gold bullion behind. Mercury amalgamation was used by the Romans (Healy 1978: 157), and Agricola described its use in detail in 1556 (Agricola 1950: 297). It was commonly used on all of the nineteenth century goldfields.

**Stamp Mill Theory of Operation**

The gravitational stamp mill worked by the very simple action of lifting a heavy weight and then dropping it on to lumps of ore. Chapter 5 describes in detail some of the many details
and design permutations of stamp mills, but the basic theory of operation in all of these variations remained the same.

The basic action was to raise a weight $W$ through height $h$ and then allow it to fall through that height onto ore placed on a die. The energy available for crushing was the kinetic energy of the falling mass:

$$Wv^2/2g$$  
(where $v$ is velocity and $g$ is the acceleration due to gravity)

or since $v^2=2gh$:

$$W2gh/2g$$, or:

$$Wh$$  
(weight multiplied by height)

(Truscott 1923: 130-131)

That is, the energy available for crushing using a weight was equal to the work done in lifting that weight (see discussion below for the definition of work), and both the weight of the stamp and the height of the lift were directly proportional to the force of the blow. The energy in this blow would then be expended on the pieces of stone in the mortar box. The softer or more malleable a material is, the more it will deform and absorb energy. A hard material, such as quartz, will deform only a small amount, meaning that only a small amount of energy is expended before the elastic limit of the material is reached, whereupon if there is enough energy in the blow some of the bonds within the ore will be broken and it will fracture. This will usually happen along existing cleavage planes where the bonds are weakest (Truscott 1923: 131; Liddel 1926: 58).

The crushing capacity (the amount of stone that could be crushed in a given time) of a mill was largely determined by the number and force of blows that could be applied. To increase the theoretical amount of possible work either the height of the drop or the weight of the stamp could be increased. However, in a stamp mill the number of blows per minute (the drop rate) was limited by the time taken for the stamp to fall, this time being directly related to the distance travelled (the drop height) and not the stamp weight, because a body falling by the action of gravity is uniformly accelerated at a rate of 32.2 feet per second, independent of the mass involved. This means that a mill with a very high drop was restricted in the number of blows per minute that it could render. Any attempt to increase the drop rate beyond a certain amount would cause what was known as ‘camming,’ where the tappet on the falling stamp struck the rising cam without having first come to rest. Because of this limitation, the best way to strike a heavier blow, and therefore increase the crushing capacity of a stamp mill, was to simply use a heavier stamp with a fast, short drop (Caldecott 1909: 60; Morison & Bremner 1900: 158). For this reason stamp mills fell into two broad categories; slow with a long drop, and fast with a short drop, with a general increase in stamp weight (but generally no increase in drop height) over time as engineers sought to increase the capacity of mills.

**Power Requirements**

*Work* is defined as the result of a force acting through space, and *Power* is a measure of work done over time. *Energy* is the ability to do work under certain conditions (Oberg & Jones
1917: 37). Work is expressed as a product of the units of force (often equated to weight) and distance. In the British system of units the basic unit of work is the foot-pound, which is the work done in raising a mass of one pound through a vertical distance of one foot against gravity (Tweney & Hughes 1961: 347). The British engineer James Watt estimated that one dray horse working an 8 hour day could raise 33,000 pounds through 1 foot in 1 minute (Clark 1897: 720), and this became that standard British unit of power: 1 hp = 33,000 foot-pounds per minute (ft-lbs/min). More recently this imperial measurement of power has been supplanted by the metric (SI) unit, the Watt (1 joule per second) (1hp = 746 Watts).

**Stamper Battery Power Requirements**

In a stamp mill each stamp was in turn raised, dropped and then raised again. The key factors in determining the power required are the stamp weight, drop height and drop rate (which are the same as the lift height and rate). The basic equation to determine power requirement is therefore:

\[
\text{Horse-power} = \frac{\text{Weight of stamp} \times \text{lift in feet} \times \text{lifts per minute}}{33,000}
\]

The effects of friction and other losses also needed to be considered, and several experimental figures were determined: Von Ryett calculated a ratio of 1:1.127 and Henry Louis calculated 1:1.202 (Del Mar 1912: 25), while H.A. Gordon (1906: 319) recommended adding a further 33%.

To apply these calculations to an historical example, the published work rates of the Phoenix Mine at Bullendale (AJHR 1898 C3: 102; Rickard 1898: 185) can be used to calculate the theoretical amount of power required to run the stamps (excluding other machinery). The Phoenix Battery in 1898 consisted of thirty 800lb stamps running at 78 drops per minute with a drop of 7.5 inches (0.625ft). The power requirement was therefore:

\[
\text{hp} = \frac{(30 \times 800 \times 78 \times 0.625)}{33,000} = 35.45
\]

If the 33% friction coefficient recommended by Gordon (1906: 319) is added to this figure, the total requirement was 47.27hp. If other equipment were added to the battery operation, such as a one or more Berdans or a Wilfley table, the power requirement would increase. Large industrial plants like the 200 head Victoria Battery at Waikino not only had more stamps, but also a much wider range of ancillary equipment.

---

3 Some of Rickard’s details are at slight variance with other contemporary sources, and allowance always needs to be made for continuous wear and replacement of worn parts.
The Origins of the Stamp Mill

Ultimately the gravitation stamp mill is simply a mortar and pestle (but used only with a hammering motion), the ‘mortar box’ being named such for a good reason. The evolution from a hand-operated mortar and pestle to a powered stamp mill required several steps, including the harnessing of natural sources of power and the development of reciprocating motion in a machine.

The basic natural forces that could be harnessed in the ancient world were wind, water and heat. Wind was certainly the first force to be utilised in the sails of sailing boats. Water was the next force to be harnessed in the water-lifting water-powered wheels (noria) that probably first appeared in the 3rd century BC at Alexandria (Wilson 2002: 7-10). The power of heat, in the form of steam, was recognised at least as early as the 1st century AD when Hero of Alexandria described the æolipile, a simple reaction steam turbine where a sphere was driven around by jets of steam issued from two nozzles set around its circumference (Bourne 1868: 2; Smiles 1865: 6). Æolipile were possibly used to drive automation figures in temples, but no other practical use for them is recorded.

All of these devices provided linear or rotary motion. Rotary motion was readily applied to the flour mill for grinding grain using round millstones, either in the direct-drive vertical mill (Bennett & Elton 1898: 27), or in the more mechanically complex ‘Vitruvian’ mill of the 1st century BC in which a water wheel drove a millstone through a set of gears (Vitruvius X: V).

The transition to reciprocating motion was probably made with the trip hammer driven by cams that may have been developed as early as the 3rd century BC in the Mediterranean, and was in widespread use for the hulling and pounding of grain in Italy by the 1st century AD (Lucas 2005: 8; Wilson 2002: 16). In China the powered trip hammer was in use during the Han Dynasty (ca. 200BC to ca. 220AD) (Needham 1965: 82).

The next transitions, from grain working to other industries, and possibly from the trip hammer to the stamp mill, also occurred in the ancient world. There is archaeological evidence from a Roman water mill site at Ickham in Kent that water-powered trip hammers were possibly used there for metal working (Wilson 2002: 16). More significantly, there is also good evidence that trip hammers or stamp mills were used for ore crushing at Roman silver and gold mines in Portugal, Spain and Wales in the 1st and 2nd centuries AD (Burnham 1997: 332-334; Wilson 2002: 21-22). This evidence is in the form of stone anvils used as the solid base for crushing, several examples of which have been found with lines of between four and ten regular parallel depressions left where hammers or stamps have repeatedly fallen (Figure 7). Archaeological excavations at Dulaucothi in Wales have confirmed the dating and association of Roman hard-rock gold mining with water-powered ore processing, and the Carreg-Pumsaint anvil stone (Figure 8) provides possible evidence for the crushing technology involved (Burnham 1997). Several authors have argued that these anvil stones were formed as the result of mechanical stamps operating within a guided framework, although whether they were recumbent hammers or vertical stamps has not been determined (Burnham 1997: 334; Lucas 2005: 8; Wilson 2002: 22). It is notable that they appear almost identical to medieval anvil stones from Devon and Cornwall (see discussion below), and for many years it was assumed that they were also medieval in origin.
Figure 7. Anvil stones from (A) Bachicon de Fresnedo (Portugal), and (B) Forno dos Mouros (Spain) (Burnham 1997).

Figure 8. Carreg Pumsaint, at Dolaucothi in Wales (Photo: Nigel Davies, www.geograph.org.uk/photo/396874).
The diffusion of industrial milling technology throughout the Mediterranean and into Northern Europe occurred between the 3rd century BC and the 1st century AD, with the Roman army possibly acting as an important agent for its spread (Wilson 2002: 11). The Dolaucothi mining evidence, and a flour mill excavated at Haltwhistle Burn on Hadrian’s Wall dated to ca. 240-270 AD (Simpson 1976), provide archaeological evidence of this spread of engineering knowledge to the very edge of the Empire. However, in the 3rd century AD much of this European industrial activity ceased as the Roman Empire foundered, and the Roman withdrawal from much of the Western Empire in the 4th century led to a loss of technical knowledge in Western Europe.

This pattern of industrial retrenchment is supported by the Greenland ice cores mentioned above in Chapter 2. Isotopic analysis of these cores indicate that atmospheric pollution from Roman industrial metal smelting peaked in the 1st century AD, declined in the 2nd and 3rd centuries, and then was at approximately normal background levels until the 7th or 8th centuries, not regaining the Roman levels until the early 11th century when German silver mines were extensively exploited (Wilson 2002: 25-26; Rosman et al. 1997). This gap in environmental pollution suggests that there was little large-scale mining (and the associated smelting) activity in much of this period. By association, it also adds to the likelihood that the stamp mill (if it was in use in the Roman mines) would have been lost from Europe in this period.

However, while the Western Roman Empire finally fell in the 5th century, the Eastern Empire (the Byzantine Empire) continued to thrive, and it appears that Roman technological developments survived (at least in part) there and beyond in the Muslim world. There is archaeological evidence from Ephesus (in modern Turkey) that water-powered sawmills were used until the 7th century, and probably later, and in the Middle East there is archaeological evidence of the widespread use of water powered mills from the 9th century (Lucas 2005: 8, 10). By the time of the Crusades (beginning in the late 11th century) there were water mills in every province of the Muslim world from Spain and North Africa to Central Asia, and by the mid-12th century the industrial use of waterpower had spread to Christian Spain (Lucas 2005: 10).

There is good evidence of water-powered grain milling in Europe from the 8th century in both France and England (Bennet & Elton 1898: 96-97; Lucas 2005: 17). By the time of the Domesday survey of 1086 there were possibly as many as 6,500 recorded water mills in England, the vast majority of which were for grinding grain (Hodgen 1936: 266; Lucas 2005: 4, 25). The appearance of water-powered industrial mills was much slower than the grain mill, and much of this early industrial development occurred in France, including the malt mill (770), fulling mill (1080), tanning mill (ca. 1134), and sawmill (1300) (Lucas 2005: 16, 19-20).

The application of water-power to metallurgical processes occurred in the 13th and 14th centuries, and was strongest in mining areas in Spain, France, England, Germany, Sweden, Poland and Italy (Lucas 2005: 22). There is some uncertainty about the first post-Roman appearance of the ore-crushing mill in Europe; Lucas (2005: 17, 27) places it in the Plauen region in Germany in 1317; but Needham (1965: 379) has found evidence for vertical stamp mills for ore-crushing in Styrian sources for 1135 and 1175 (Styria is in modern Austria). Unequivocal evidence of the use of the vertical stamp mill in Europe by the 15th and 16th centuries is provided by several sources. The manuscript of an anonymous Hussite engineer dated ca. 1430 (although some scholars suggest ca. 1480) illustrated a vertical pestle stamp
mill used for gunpowder manufacture (Figure 9) (Reynolds 1983: 364; Needham 1965: 394), while Georgius Agricola in his *De Re Metallica* (first published in 1556) illustrated and described stamp mills and ore processing technology that would remain virtually standard until the mid-nineteenth century.

**Figure 9. A vertical pestle mill dated to ca. 1430 (Needham 1965: Figure 619).**

*De Re Metallica* was a pivotal work in mining history, and provides the best available account of medieval metallurgical practices. The work was based largely on Agricola’s observations in and around Joachimsthal, a small town in Bohemia in the midst of what was the most prolific metal-working region in Europe at the time (Agricola 1950: introduction by Hoover & Hoover: vii).

Agricola’s detailed descriptions and illustrations clearly show that the stamp mill was well-developed by the mid-sixteenth century, and had achieved a form that would change little until the Californian stamper evolved in the mid-nineteenth century. Of particular note in Agricola’s mill was the square-section timber stamp stem with square stamp head, and the large-diameter cam shaft (or cam barrel) that had pegs inserted in holes to lift the stamps as the drum revolved (Figure 10). He described both dry and wet crushing (Figure 11), and claimed that the latter had been introduced in the early sixteenth century by Sigismund Maltitz of Meissen (Agricola 1950: 312).

In addition to the stamp mill, Agricola’s work also described the other metallurgical processes, including secondary grinding of crushed ore and various methods for washing the pulp, proving that the whole ore milling process had reached a high level of complexity and mechanisation by that period. This evidence of technological maturity in the industry suggests strongly that it already had a long tradition, questioning the common interpretation that the stamper battery was probably developed in the late fifteenth or early sixteenth century in Europe (eg Morrell 1968: 8).
Figure 10. A mid-sixteenth century stamp mill for dry crushing, as illustrated in Agricola’s De Re Metallica (Agricola 1950).

Figure 11. A mill designed for wet crushing as illustrated in Agricola’s De Re Metallica (Agricola 1950).
The Stamp Mill in Cornwall & Devon

In England tin ore deposits had been found in the counties of Cornwall and Devon before the Roman invasion of Britain (Herring & Rose 2001: 47). The earliest tin mining (of an antiquity still unknown) concentrated on shallow alluvial and eluvial deposits, but by the 14th and 15th centuries, much of the easily-won tin had been mined, and attention was turned to the hard-rock tin lodes (Herring & Rose 2001: 56; Newman 1998: 21). The mining and processing of lode ore required an increased degree of mechanization, and the stamp mill and the crazing mill were both used (Gerrard 1989: 9). The stamp mill was first recorded in Cornwall in 1400 and Devon in 1504, although undocumented mills would have been in use earlier. It is likely that the first mills were built for dry stamping, but by the second half of the 16th century wet stamping had become standard practice (Gerrard 1989: 9-10; Newman 1998: 42). The archaeological evidence of the early West Country stamp mills consists of a number of anvil stones (or mortar stones) with depressions worn by the falling stamps (eg Newman 1998: 43) (Figure 12), of an almost identical appearance to the much older Spanish, Portuguese and Welsh anvil stones discussed and illustrated above.

Figure 12. Mortarstone (anvil stone) at Runnage on Dartmoor, Devon (Newman 1998).

In 1778 William Pryce of Redruth in Cornwall published Mineralogia Cornubiensis, A Treatise on Minerals, Mines and Mining, a classic work that described the Cornish mining industry in detail. While being 200 years newer than Agricola’s work, the technology he described was in many ways little changed, although one great advance was the introduction of the steam engine that had enabled deep pumping of mines (Pryce 1778: 153, 307-313). What this work does illustrate is how closely allied Cornish mining was to European technology of the period, and how well-developed and relatively standardised this technology had become. In particular, the stamp mill illustrated by Pryce differed very little from the mill illustrated by Agricola, even down to the direct drive of the cam barrel from an overshot water wheel (Figure 13). This type of mill became to be widely known as the ‘Cornish’ mill, because of its widespread use in that county, although Louis (1902: 94) also referred to the ‘Saxon’ mill of very similar design.
Figure 13. Cornish stamp mill as illustrated in Pryce’s Mineralogia Cornubiensis of 1778.

Figure 14. A cross-section of a set of nineteenth century tin stamps (Andre 1878).

This basic form of the Cornish/European stamp of the eighteenth century continued in use through the nineteenth century and even into the early twentieth century in some mines in Devon and Cornwall (Figure 14). It was in this form that the stamper battery travelled to the New World goldfields of the mid-nineteenth century. The stamp mill was about to undergo a major technological evolution in America.

**The Development of the ‘California Mill’**

The main international gold rushes of the mid-nineteenth century (discussed in Chapter 4), beginning in California in 1848, set the scene for a major evolution in gold milling technology. The stamper battery that had remained almost unchanged for 300 years would very quickly evolve (‘redesign’ suggests a too definite and deliberate process) to become the
‘Californian Stamper’ or ‘California Mill’ that would then dominate the gold milling industry until the early twentieth century.

According to Del Mar (1912: 4) the first stamp mill in the United States was started in about 1835 at Tellurium in Virginia. This was equipped with square-section wooden stems with iron shoes and dies, and was therefore little different to the mills illustrated by Agricola and Pryce. Similar mills were in use in the State of Georgia at about the same time (Del Mar 1912: 4; Rickard 1898: 8), and according to the American mining expert T.A. Rickard, the Georgian methods had been influenced by ‘the classic regions of Transylvania,’ or more specifically, Verospatok and Nagyag in Hungary (Rickard 1898: 8, 194, see also Louis 1902: 94). Conversely, A.B. Paul (1895: 522-523) suggested that a stamp mill that he saw in 1847 at the Eagle River Copper Mine on Lake Superior was based on English practice. These sources make it clear that there was a strong European as well as British/Cornish influence on the introduction of stamp milling to the United States.

The advent of the California gold rush in 1848-49 gave mining a great impetus, and once quartz reefs began to be exploited from 1850 stamping technology was imported from the existing mills within the United States, and the first stamp mill in California was probably built in Mariposa County (Paul 1895: 524). There is some disagreement about where the direct influence for the first stamps in California came from; Paul (1895: 523) stated that the first California mill was a duplicate of the Eagle River Copper Mine Stamp (and the influence was therefore English, probably Cornish), while Rickard (1898: 8) and Del Mar (1912: 4) both stated that the technology came from Georgia (and the influence was therefore European). However, Rickard (1898: 35) also commented that the earliest quartz mining area in California, Grass Valley, had a population that consisted mostly of Cornishmen, meaning that there was almost certainly a strong Cornish influence there. Davey (1996: 60) has suggested an additional possible influence from the Urals, in Russia, based on contemporary reports. Deciding which account is correct is problematic, but it is likely that all are in part right, and that in a young country with many immigrants the influences were mixed from the very start of the gold rushes.

Figure 15. Cross-section of ‘earliest Californian mill’ erected by W.S. Moses (Del Mar 1912).

An example of one of these early mills in use in California is shown in Figure 15. Whatever the truth is regarding the immediate origin of the technology, comparison with Agricola’s and Pryce’s illustrations shows that (with the exception of a geared drive) the basic form and operation had not changed since at least the mid-sixteenth century.

What then happened in California was a rapid evolution in design to create what Limbaugh’s
(1998: 41) has referred to as a “regional hybrid”: the Californian mill. Philips (1867: 172) provided a contemporary description:

In California, however, another arrangement is employed for imparting motion to the pestles or stampers of a battery with wooden stems. Instead of a large cylindrical axle, a wrought iron shaft is made use of, and on this are keyed a series of long curved cams, which enter mortise or slot holes, in the several stems, and cause them to be alternatively lifted and released, precisely as in the case of the ordinary stamping mill, provided with tappets and a drum axle. When wooden stems are made use of, they are usually about six inches square, and cut out of ash, or some other hard wood, having a straight grain. These wooden stems with square heads have, however, been almost universally superseded by the rotary stamp, with a round stem of iron, to which a circular motion is given by the friction of the cam in lifting, and which, being continued up to the moment of its release, is prolonged during its descent, thus imparting a grinding action to the cylindrical head at the moment of its coming in contact with the rock to be broken.

This account describes the critical evolution from the cam barrel to the cam shaft, and the square stamp stem to the round rotating stamp stem, that were the two key design changes that transformed the old ‘Cornish’ mill into the ‘California’ mill (although Philips was mistaken about the grinding action of the rotating stamp). This was a period of rapid innovation, and further changes were added. A summary of all of the main transformations was succinctly provided by Del Mar (1912: 4-5):

No great advance was made on the form of mill used in the Appalachian States of America until C.P. Stanford introduced the round stem from which followed the round shoe, die and boss-head; J. Fish suggested revolving the stem to equalize the wear on shoe and die; J. Wheeler and H.B. Angel invented the method of holding the tappet on the stem by means of gib and key and J.M. Scott constructed the double armed cam. These were all inventions of men operating in California and proclaim the modern stamp mill, the California Mill.

Of these innovations the revolving stamp was the most important, as it “prevents all irregular wearing of shoes and dies, and thus fully doubles their work” (Paul 1895: 528). The exact time and place of the first appearance of the revolving stamp has been variously stated; Paul (1895: 528) said that it was adopted in 1852 at a mill on the Cosumne (the Cosumnes River in northern California), and was the idea of engineer Issac Fisk. Alternatively, Rickard (1898: 35) thought that the first mill with revolving stamps was probably constructed in Mariposa County (in central California) in 1850. Paul was in California in the 1850s, and Rickard was an acknowledged expert in milling practice, so both men’s opinions carry weight, and the exact primacy of the revolving stamp remains uncertain. However, it had most certainly appeared by 1852, and had an unbroken history of use from that time on.

Closely associated with the rotating stamps was the new cam design, with a double-armed iron cam mounted on an iron shaft replacing the earlier large-diameter barrel and stud cams. It is possible that the cam was actually the first component to begin to evolve in California, as

---

4 Paul (1895: 527) stated that the inventor of the revolving stamp was Fisk, but otherwise agreed with the main details given by Del Mar.
Paul (1895: 524, 526) described the use of cams with curved arms “copied after the long horns of the California bull, long and slightly curved” in a mill still fitted with square section stamps in 1851. The final cam design was arrived at in stages, with cams with wide hubs and single arm cams produced before Irving Scott of the Union Iron Works produced the final two-arm pattern that included the mathematically calculated curve (Paul 1895: 528).

The gib tappet (see Chapter 5) was probably designed slightly later, as it was preceded by the screw tappet that could only have been used on a round stamp stem. The screw tappet was considered out of date by about 1870 (Louis 1902: 169), suggesting that the replacement gib design was introduced in the 1860s.

Paul (1895: 527-529) also added the high iron mortar, upright mortar blocks (the vertical timbers that supported the mortar box) and the latches (or jack fingers) for holding up individual tappets to the list of parts of the modern (in 1895) California Mill. These improvements were also made in stages, and Paul described some of the process of improvements of the mortar box, while Rickard (1898: 35) commented that the first mill with rotating stamps had single mortars, one for each stamp. The latches or jack fingers are likely to have been the last major improvement, and are not generally included in the list of key parts of the California Mill by other contemporary authors.

By 1870 it was rare to see a stamp mill with square stems (Raymond 1870: 657), which means that 20 years (possibly even 10 years) of innovation in California had completely changed a machine that had existed largely unaltered for at least 300 years. Some continuing regional differences in operational parameters led some authors to differentiate between ‘California’ mills (short and fast stamp drop) and ‘Colorado’ mills (long and slow stamp drop) (Rickard 1898: 5), but the basic pattern of rotating stamps and iron camshaft with double-arm mathematically correct cams, that became widely known as the California Mill (or Californian Stamper), had been established (Figure 16).

**Figure 16. The evolved form of the California Mill (Andre 1878).**
The International Movement of Stamp Milling Technology

The 20 years from 1850 to 1870 were a period of radical change to the stamp mill, but in the same way that the immediate progenitor of the Californian Mill was not clear, the subsequent movement of the new milling technology was not simple, linear or uni-directional.

The next major gold rush after California was in Australia in 1851 (see Chapter 4). Although there had been some earlier copper mining in South Australia that had used Cornish technology operated by Cornish miners, this had been hard-rock mining, and the alluvial mining technology used on the first Australian gold fields was heavily based on Californian practice (Blainey 1993: 15; Davey 1996: 52-53; Menghetti 2005: 205; Reynolds 1974: 13-15). However, several Australian authors have debated whether the subsequent development of quartz crushing equipment was directly based on Californian practice, European (including Cornish) practice, or was a local innovation albeit influenced by those places (Davey 1988; Davey 1996; Menghetti 2005). Certainly the history of the first few years of the introduction of stamp milling to the Australian goldfields was complex.

Davey (1988: 8) found that the first quartz crushing ‘machines’ were introduced to Australia in 1852 by some English people, but no details are available to determine the actual nature or design of these machines. At Ballarat a hand-operated three-stamp battery was possibly worked by Lancelot Stormont in 1852, and was claimed to have had round stamps (Davey 1996: 57). The simple crushing dolly using a weight attached to the end of a felled sapling was in use in 1853 and 1854, indicating that simple hand-working methods were commonplace while the reefs were tested, but in 1854 mechanised stamper batteries started to appear. A German, Ballerstedt, operated a horse-powered dry-crushing machine at Bendigo in 1854, but so much gold was left in the tailings that these were reprocessed the following year by Ballerstedt and two Americans, Denis and Ferguson, who erected a steam-powered battery in March 1855 (Davey 1988: 9; 1996: 56). As Ballerstedt had been in California prior to Australia, it is possible that he could have had knowledge of both German and Californian milling practice, while Denis and Ferguson would have been familiar with Californian techniques.

A Mr. Hustler also erected a battery at Bendigo in 1854. He and his first working associates were American, and he was granted a Victorian patent that year for an unusual belt-lifting method of lifting the stamps in a mill (Davey 1988: 9; 1996: 56). Then Latham and Watson (who had apparently been associated with Hustler) erected a battery that had wooden stamps shod with iron, and used curved cams for lifting the stamps (Davey 1988: 9; 1996: 56). The battery was run in conjunction with shaking tables that were introduced from California, and it is therefore a reasonable conclusion that this battery represents the importation of semi-evolved Californian Mill technology.

In June 1858 William Stevens of Bendigo patented a stamp battery design with curved cams and round rotating stamps (Figure 17) (Davey 1988: 10; 1996: 56). Both Davey and Menghetti (2005: 206) have treated this as a significant Australian design, with possible admitted American influence, but it seems clear that despite the granting of a Victorian patent (although this was later challenged and lost) it was merely a direct copy of what was already a well-established Californian design. By 1858 the main elements of the Californian Mill had appeared (as described in detail above), and there was ample time for this information to be widely disseminated and to cross the Pacific Ocean. What the patent drawing of Stevens’ stamp mill does prove is that the California Mill was present in Victoria by 1858.
While the appearance of Californian design features can therefore be identified in some early Australian stamp mills from at least 1858, many other mills followed Cornish/European patterns, in particular in the use of square section stamp stems and cam barrels. The choices of technology appear to have been closely allied to the experience and background of the people involved. Where professional European miners or engineers were in charge the ‘Cornish’ pattern of stamps was extensively used (Davey 1996: 57). Rickard (1898: 199) stated that the first treatment process used by the Port Phillip Company at Clunes (in 1857) was largely founded on that of tin dressing as conducted in Cornwall, and that the stamp heads were square, making it clear that a Cornish stamp mill was in use. This is not surprising because much of the company’s capital came from England, and an English consultant, Evan Hopkins, advised on the battery construction (Davey 1996: 57).

The movement of stamp mill technology to New Zealand started in the aftermath of the 1861 rush to Gabriel’s Gully in Otago. The first known stamp mills in New Zealand were Keven’s Battery in the Coromandel and the Otago Quartz Mining Company Battery at Waipori in Otago, both of which started crushing in January 1863 (Daily Southern Cross, 7 January 1863: 3; 8 January 1863: 3; OPC V&P Session XVII 1863: 16; Salmon 1963: 180). The machinery for Keven’s Battery was ordered from Melbourne, probably from the Carlton Foundry of A.K. Smith (the company was certainly advised by Smith, a Victorian mining engineer) (Daily Southern Cross, 5th July 1862: 4; 31 October 1862: 9). The first Otago Quartz Mining Company battery was a 4 stamp mill driven by water power, and was of the ‘Cornish’ pattern with square stems (Otago Daily Times, 11 October 1864: 5). However, it was soon replaced with a ten stamp mill imported from Smith’s Carlton Foundry in Melbourne, and a good description of this machinery was given in a newspaper report on the occasion of its opening:

Later to become the Otago Pioneer Quartz Company, generally abbreviated as the ‘OPQ,’ by which it is better known.
The whole of the plant is from the works of Mr. A.K. Smith, Carlton Foundry, North Melbourne, and is creditable to that gentleman as it is to Mr. Fulton for the manner in which it has been put together. In neatness of finish, compactness, apparent durability, and absence of vibration, the writer of this has rarely seen it equalled and never surpassed in Victoria. There are two batteries of five revolving stamps, each stamp weighing, when mounted, 5 cwt., and a very marked improvement is noticeable in the substitution of a screw or thread and key nut whereby to fix the discs instead of the old manner of having them keyed on to the stalk. The stamps are fed by hand, and the boxes have front, end, and back deliveries. (Otago Witness, 18 June 1864: 16)

This first-hand account makes it quite clear that this was a ‘California Mill,’ complete with the diagnostic revolving stamps (and by association, the improved cams and camshaft), and also that this technology was brought to New Zealand via Australia rather than directly from California. However, the old-fashioned ‘Cornish’ mill was also used in New Zealand’s early goldfields, the best evidence of this being a photograph of the 1867 Great Expectations Battery (Figure 18) published in the Auckland Weekly News (20th December 1906: 8). There are a number of references to ‘Cornish stamps’ in some contemporary sources (for example, OPC V&P Session XX 1865: 92 lists 12 ‘Cornish stamps’ in the Upper Shotover Division). It is therefore clear that from the very outset, New Zealand’s hard rock gold mines had access to the both the California Mill and the earlier Cornish Mill.

Figure 18. The Great Expectations Battery at Thames in 1867 (Auckland Weekly News 20th December 1906, Sir George Grey Special Collections, Auckland Libraries, AWNS-19061220-8-2).
Chapter 4

The Nineteenth Century Gold Rushes: America, Australia, New Zealand, South Africa

In the second half of the nineteenth century there were a series of major international gold rushes, which can be very broadly be summarised as California (1840s), Australia (1850s), New Zealand (1860s), South Africa (1880s). The first three of these are often described as the Pacific Rim rushes. Once established, the mining industry in each country grew and developed, so that by the time New Zealand’s mining industry was established it could draw on both the past experiences and continuing developments of the older fields, and in turn could itself contribute to these developments.

Although the New Zealand experience differed from the earlier fields, it must be seen in the context of these earlier events, and many of the participants in the early New Zealand gold rushes had been in California and/or Victoria previously. Of particular note is that New Zealand mining regulations were based on those of Victoria, and some of the earliest gold stamping machinery imported into New Zealand came from Melbourne. While not one of the Pacific Rim goldfields, South Africa’s goldfields were also influential, and in particular the region was a leader in the development of heavy stamp mills.

This chapter describes briefly the early events of each of these rushes, and the start of hard rock (quartz) mining in each place. California, Australia and South Africa are considered briefly first, and then more time is spent discussing the New Zealand goldfields. This Chapter is not meant to reassess or reinterpret these goldfields, or even provide detailed histories, but rather to place the discussion of New Zealand’s quartz stamp mills in a general international and historical context.

The American Goldfields

The Spanish conquistadors’ seizure of the Inca and Aztec gold in the 16th century took American gold onto the world stage, and for the next 200 years the Spanish American goldfields were worked using cheap slave or Indian labour (Gregory 1980: 100-104; Morrell 1968: 12). The Spanish imported established European mining technology, and adapted it for the drier South American conditions (Burt 2000: 325; Limbaugh 1998: 25).

The first recorded gold discovery of note in North America was made in 1799 in North Carolina, and other discoveries followed in 1828-29 in northern Georgia where by 1830 thousands of miners were working (Morrell 1968: 74-75). The importance of these early rushes was not so much their economic effect, but that at least some of the men who joined the later Californian rush had some mining experience (Morrell 1968: 76).

Gold was found in California as early as 1842, but the historically significant discovery was made in January 1848 by J.W. Marshall in the tailrace of a sawmill being erected for J.A. Sutter. By March 1848 news of the discovery at Sutters Mill appeared in the newspapers, and in May the rush began. By mid-August some 4,000 men were estimated to be at work, and 10,000 by the end of the year (Morrell 1968: 77-79). As more diggers arrived, they spread out from the original discovery, prospecting new areas until the arrival of winter in October restricted operations.
There were no published mining regulations in 1848, partly because California had only recently become United States territory, and in the US the principle of Royal (or State) ownership of gold (also known as the ‘regalian’ system) did not apply as it did in many other places (Gregory 1980: 191-194). Official policy encouraged individual initiative and development, and control over claims was left to the mining population (Morrell 1968: 81-82). As the goldfields population rose (particularly in 1849) and pressure for workable ground increased, camp committees were established, and mining regulations and basic legal codes were drawn up by the miners themselves, often with considerable variation from place to place. The same approach was taken on other American goldfields, such as in Colorado, and it was not until 1866 that Congress passed the first measures to determine claim sizes (Hollister 1867: 75; Morrell 1968: 195).

In 1849 the Californian rush really got underway (hence the famous ‘Fortyniners’), and one estimate is that 81,000 people had travelled to California by the end of 1849, with another 91,000 the following year (Morrell 1968: 84, 96). All of the early workings were on ‘placer’ deposits: alluvial gold deposits in rivers, streams and banks. The methods for working these deposits were already well developed, and were imported indirectly through Spanish South America (Burt 2000: 325; Limbaugh 1998:25).

Auriferous quartz was first found at Grass Valley in June 1850 (Morrell 1968: 98; Rickard 1898: 35). A first quartz boom occurred in 1850-51, based on a few very rich lodes and optimism. Crushing was carried out using stamp mills with square timber stamp stems and cast iron shoes, and the Mexican arrastra. After a decline, the industry began to revive in 1853, and by 1855 there were about 60 stamp mills in operation (Morrell 1968: 102). As described in Chapter 3, it was in this period that the distinguishing features of the ‘California Mill’ emerged (Phillips 1867: 172; Rickard 1898: 35). The Grass Valley district continued to be a strong quartz mining area, and by 1890 there were 58 mines and 295 head of stamps in operation there (Rickard 1898: 36). In addition, the discovery and exploitation of the Comstock silver deposits in the 1860s and 1870s did much to make underground mining a major industry in the United States (Burt 2000: 326; Morrell 1968: 140-150).

The Australian Goldfields

The first confirmed record of Australian gold was made in 1823 by the surveyor James McBrien near Bathurst, but his observation was soon forgotten (Blainey 1993: 6). After a number of other un- or under-reported finds, the discovery of alluvial gold in payable quantities is credited to Edward Hargreaves who together with John Lister and the Tom brothers found gold in the banks of Summer Hill Creek at Ophir near Bathurst in New South Wales in 1851, and the resultant rush was the first of its kind in the British Empire (Birrell 1998: 1, 9; Blainey 1993: 13-19; Stone & Mackinnon 1984: 8; Thames Miner’s Guide 1868: 57). It was followed by discoveries at Ballarat and Bendigo in Victoria, and by 1855 there were 15 goldfields (Thames Miner’s Guide 1868: 58). The discovery of the Queensland goldfields was somewhat later, starting in 1858 at Rockhampton and continuing into the 1870s, and the Western Australia goldfields were found later again, in the 1880s (Morrell 1968: 283-289, 305).

As in California, the early discoveries were alluvial deposits where the easily-worked shallow ground was mined first (Figure 19), and the deeper gold (such as the deep leads at Ballarat)
required more time, effort and capital to exploit. Also in common with California, as new finds were made diggers surged between the different mining fields, pursued by storekeepers and other camp followers, and bolstered by new arrivals landing in Melbourne. The numbers on the Victorian goldfields reached their peak of about 147,000 in 1858 (Morrell 1968: 246).

Figure 19. Early alluvial gold mining in Australia (Garran 1886).

The approach to the administration of gold mining in the British colonies was very different to the self-regulating laissez-faire approach of the United States. This was because of two main factors. Firstly, in the British colonies gold was considered to be Crown property, and therefore the government expected to exercise control over its extraction and realise a proportion of its value. Secondly, there was already a functioning government in place in New South Wales and Victoria (and later New Zealand). In order to regulate the first rush to Ophir the New South Wales Government introduced a licencing system, whereby all diggers had to purchase a licence at 30 shillings per month before they could legally mine for gold (Blainey 1993: 20, 22). The adoption of the same licencing system in Victoria would cause great dissention within a few years.

One of the significant early events of the Australian goldfields, and one that affected the way the later New Zealand goldfields would be administered, was the storming of the Eureka Stockade at Bendigo in 1854. This episode had its origins in the events of three years earlier. The 1851 gold rushes had come at a time of some political transition in Australia, as the Port Phillip District was only separated in that year from New South Wales to become the colony of Victoria (Birrell 1998: 9). The new Victorian Government was not prepared or equipped to deal with the gold rushes, and so it followed the lead of the New South Wales Government, particularly in the case of the licence and fee (Blainey 1993: 32). In August 1851 the new regulations for gold fields in Victoria were published, containing six clauses (Birrell 1998: 13):

- Licences to mine gold would be required from 1 September.
- Each licence would be for one month at a cost of 30 shillings.
Licences would be issued on the spot by the commissioner who would also determine the size of claim.

Each applicant was to produce a certificate of discharge from his previous employer.

Licences would only be issued for unalienated Crown land.

Landowners wishing to mine on their land were to apply to the government for licences.

Commissioners were stationed at each goldfield, and were supported by a staff that included armed constabulary who were responsible for checking licences, and any miner caught without one could be fined £5 (Birrell 1998: 18-19). Resentment amongst the miners at the regime grew due to a number of reasons, including the licence fee of 30 shillings a month irrespective of the amount of gold won, dissatisfaction with the administration of mining lease areas, the desire for political representation, and the need for land to enable miners to build a house, keep livestock and grow food (Birrell 1998: 23).

This unrest came to a head at Ballarat in November 1854 when 800 armed miners formed a stockade at Eureka, burnt their licence papers and raised a flag of defiance. On December 3rd Commissioner Rede sent the local police and armed troopers in to storm the stockade, and in the fight 23 miners and 5 soldiers were killed and numerous prisoners were taken (Figure 20). Although the miners lost the fight, in the aftermath a commission was appointed to investigate the grievances, and in 1855 the licence fee was replaced by the Miner’s Right at £1 a year, holders of a Mining Right were entitled to vote in the election of the Local Courts and Legislative Council, an export duty of 2s. 6d. per ounce on gold was introduced, and the position of Commissioner was replaced by a Warden (Birrell 1998: 29-39; Blainey 1993: 55; Garran 1886: 171; Morrell 1968: 244-245; Thames Miner’s Guide 1868: 59). The other auriferous Australian colonies soon followed suit.

Figure 20. The storming of the Eureka Stockade in December 1854 (Garran 1886).
Australian Quartz Mining

There were several forces at work against quartz mining in the early 1850s. One consequence of the early mining legislation that limited claim sizes was to hinder the development of larger companies. Small leases did not justify large capital expenditure, which was a particular problem for quartz mines that required expensive winding and crushing equipment (Birrell 1998: 39, Morrell 1968: 250). But by 1858 the easily-won gold was becoming worked out, and it became apparent that larger companies would be needed to profitably work the remaining deposits (Birrell 1998: 65, 69).

Gold-bearing quartz reefs were first found at Clunes in Victoria in 1851 and large-scale quartz mining started there in 1857 (Figure 21), although the first mechanised processing of quartz had begun in 1854 at Bendigo (Birrell 1998: 12; Davey 1996: 56; Whiting & Brown 1976: 434). The Port Phillip and Colonial Gold Mining Company was floated in London in 1851, and selected the Clunes find for their mine because it was on freehold land, and therefore not subject to the control of the Local Courts. The Company’s battery began operation in 1857, and initially used Cornish milling practice. The Company was successful because it efficiently ran at a large scale and continuously adopted up-to-date technology, allowing it to profitably treat low-grade ore (Blainey 1993: 66-69; Rickard 1898: 102, 117, 199). This demonstrated the way that the quartz mining industry had to evolve, and by the 1860s Victoria’s quartz mines were heavily mechanised with some 500 steam engines at work (Blainey 1993: 59, 68-69).

Figure 21. The Port Philip & Colonial Gold Mining Company’s operation at Clunes (Garran 1886).

South Africa

Alluvial gold had been mined in Africa for centuries before European colonisation, and was traded through long networks to the Mediterranean and various coastal ports. The Portuguese
established a presence in West Africa in the 15th century and engaged in trading gold, and later the French, English and Dutch competed for the same trade (Morrell 1968: 8-9).

In the European/historic period gold was probably discovered in South Africa in the Crocodile Valley in 1853 but the field was not payable. Between 1866 and 1886 a number of discoveries were made, some leading to rushes and boomtowns, but the most important discoveries were made in the Witwatersrand (the Rand) from 1885 (Morrell 1968: 313-315, 337-343). The main reef was discovered in 1886, but it was a vast body of low-grade ore that required large scale and economical mining and processing to be profitable (Morrell 1968: 345). Almost from the first it was controlled by wealthy capitalists who had already made fortunes in the Kimberley diamond mines. After the diamond fields were first discovered in 1867 a series of mining companies were established, and these ultimately combined as De Beers Consolidated Mines Ltd in 1888 (Morrell 1968: 335). The Rand goldfield was opened with this legacy of capital investment and large-scale mining, rather than the small-scale workings of the individual digger that California, Victoria and New Zealand had seen.

A notable feature of the Rand was its technological progress, largely in response to the low grade and pyritic nature of the ore. Despite setbacks, such as the Anglo-Boer War of 1899-1902, the mining industry at the Rand by the end of the nineteenth century had a level of mining and metallurgical skill as high as any other goldfield in the world (Morrell 1968: 362). The MacArthur-Forrest cyanide process was introduced in 1890, and the South African mines were leaders the use of very large mills (Figure 22) where stamps up to 2,000lb in weight were in use by 1900, at a time when stamps of half this size were considered heavy in New Zealand (Del Mar 1912: 12, 12; Gowland 1914: 202).

Figure 22. The largest battery in the world in 1911, the Central Mill at Randfontein, Johannesburg (Sir George Grey Special Collections, Auckland Libraries, AWNS-19111012-2-1).
The New Zealand Goldfields

The main New Zealand gold fields were (from the north) the Hauraki and Ohinemuri fields (including the Coromandel, Thames and Waihi areas), Nelson and Marlborough (including the Whakamarina and Collingwood fields), Westland, Otago and Southland (Figures 23 and 24).

Figure 23. The mineral deposits in the North Island (New Zealand Mines Record, 1906)
Figure 24. The mineral deposits in the South Island (New Zealand Mines Record, 1906).
The Start of the New Zealand Gold Rushes

Gold had been reported in small quantities in the Coromandel and Collingwood areas in 1842, with a possible earlier find near Thames, but it was the exodus of men to the Australian goldfields in 1852 that led a committee of Auckland businessmen to offer a £500 reward for the discovery of a New Zealand goldfield in order to stimulate the local economy (Bell 1912: 14; Salmon 1963: 26, 30; *Thames Miner’s Guide* 1868: 60). In October 1852 Charles Ring discovered gold at Driving Creek on the Coromandel Peninsula, and New Zealand’s first small gold rush ensued. After negotiations with the Maori landowners the area was opened for mining, and regulations were issued based on Victorian mining ordinances, with a licence fee of 30s. per month being charged with an initial 2 month exemption (*Thames Miner’s Guide* 1868: 61) (it must be remembered that this rush occurred before the introduction of the £1 Miner’s Right in Victoria). However, by mid-1853 the rush was over and the field deserted, because as would later become clear this was predominantly a quartz field, with little free alluvial gold for the individual digger to find (Bell 1912: 14-15; Salmon 1963: 26-30).

New Zealand’s second rush was in Nelson in 1857, after gold was found at Lightband’s Gully, and subsequently at Parapara and at Appo’s Flat (Salmon 1963: 32). By May 1857 some 1,500 miners were in the Aorere district, rising to about 2,000 in early 1858 (Salmon 1963: 35; *Thames Miner’s Guide* 1868: 63). The regulations in this field were drawn up by the prospector William Lightband, accepted at a public meeting and published in the local press (Salmon 1963: 33). Although relatively small, the early Nelson rushes were more enduring than the earlier Coromandel rush because relatively easily won alluvial gold was present (Salmon 1963: 37).

An important effect of the Nelson rush was to encourage the New Zealand government to put in place legislation to manage new goldfields. The first *Gold Fields Act* was passed in 1858, and this introduced the £1 per year Miner’s Right and system of Goldfields Wardens based on the Victorian model (*Gold Fields Act* 1858: II, XV; Morrell 1968: 260; Salmon 1963: 21, 38). Therefore, unlike California, New South Wales and Victoria, New Zealand had a functioning (and to a degree, proven) legal framework for goldfields management prior to the main rushes starting in 1861.

In Otago and Southland there had been hints of the presence of gold as early as 1849, and small amounts were found throughout the 1850s (*OPC V&P Session XVI* 1862: 15-16; Salmon 1963: 46). There was official resistance to the thought of a gold rush from the Otago establishment, but after the Nelson goldfields threatened to lure Otago labourers away attitudes began to change, and in December 1858 a reward of £500 was offered for the discovery of a payable goldfield (Pyke 1962: 14; Salmon 1963: 47). During 1858 Alexander Garvie found gold in the Lindis River, and Edward Peters (‘Black Peter’) found gold in a number of places, including Evans Flat and Woolshed Creek. The first rush in Otago occurred at the Lindis Pass in 1861 when workmen found gold while building a road, and 300 men were there by the end of April, but winter and the events at Gabriel’s Gully brought it to a rapid end (Pyke 1962: 22).

Gabriel Read was an Australian and a veteran of both the Californian and Victorian goldfields (Hearn in Oliver ed. 1990: 358), and while following up on some of Edward Peter’s discoveries he made his discovery of gold at Tuapeka in May 1861. By the beginning of August 1861 at least 2,000 men were camped at Gabriel’s Gully (Figure 25), and in mid-September J.T. Thomson estimated that there were 3,000 men in the gully and 6,000 in the
overall area (OPC Gazette 26th September 1861: 238; Salmon 1963: 54). Between December 1860 and December 1861 the population of Otago rose from 12,691 to 30,269, and by the 1870s Dunedin had grown to become New Zealand’s largest city (King 2003: 209; OPC V&P Session XVI 1862: 17). Goldfields regulations were issued in late 1861, but were substantially revised by Vincent Pyke (who had been active in the development of Victorian goldfields legislation) the following year, with an increase in allowable claim size from 24 feet square to 45 feet square being one important change (Gold Fields Act 1862: II, 2; Pyke 1962: 61; Salmon 1963: 67).

**Figure 25. Gabriel’s Gully in 1862.**

In 1862 an even larger rush struck Otago, after two Californian miners, Horatio Hartley and Christopher Reilly, walked into the office of the Dunedin gold receiver and deposited 1,047 oz. of gold that they had recovered from the beaches of the Molyneux (now Clutha) River (Hearn, in Oliver (ed.) 1990: 178; OPC V&P Session XVI 1862: 18; Salmon 1963: 80). By September 5th some 3,000 men had arrived at the Dunstan, the goldfield was proclaimed on 23rd September, and prospectors quickly moved further afield (Figure 26) and found gold in the Nokomai, Shotover and Arrow Rivers (OPC V&P Session XVI 1862: 19; Salmon 1963 : 81, 83). By 1869 seven Otago goldfields had been declared: Tuapeka, Dunstan, Teviot, Nokomai, Wakatipu, Mt. Ida and Taieri (Salmon 1963: 101).
Further north, the Marlborough Provincial Council offered a £1,375 reward for the discovery of a payable goldfield in August 1863, and in April the following year four prospectors found gold in the Wakamarina River (Johnston 1992: 57, 64). The resultant rush drew many miners away from Otago, but it proved to be short-lived as the easily-won gold was in pockets that were soon worked out, and it was rapidly overshadowed by the West Coast rush of 1864 (Johnston 1992: 83; Salmon 1963: 125-126; Thames Miner’s Guide 1868: 65).

Gold had been found in the Buller River in 1859, followed by other finds on the West Coast, but the Otago rushes took attention away from that area (Salmon 1963: 39-42). Nevertheless, numbers on the coast slowly grew as gold was found in the Taramakau, Arahura, Kaniere and other rivers, and in March 1865 the Canterbury Provincial Council proclaimed the whole of the area west of the ranges and south of the Grey River a goldfield (Morrell 1968: 273, 275; Salmon 1963: 136). The West Coast was far more rugged and dangerous than the locations of the earlier rushes, and the risks of drowning and starvation were always present, but despite these hazards by the end of 1865 the population on the Coast had reached about 16,000, and this probably doubled during 1866 (Salmon 1963: 138). The last of the major alluvial rushes occurred at Kumara in 1876, although some minor rushes such as that to Rimu in 1882 followed (May 1969: 41; Salmon 1963: 171).

**The Beginning of Hard-Rock (Quartz) Mining in New Zealand**

All of the successful early rushes were to alluvial fields, and the easily-won gold was quickly depleted. Capital and co-operation was required to being to work on a larger scale, and by 1865 the ‘day of the individual miner and of the small party had already passed’ in Otago, and the same was soon true of the West Coast (Salmon 1963: 102, 152). From the very outset it was virtually impossible for a single miner to profitably work a hard rock lode, and the first hard rock mines were worked by small partnerships that soon evolved into more formal companies as capital was sought for machinery and development work.
On the Coromandel there was a second attempt by Auckland interests to establish a goldfield in 1861 in response to the exodus to the Tuapeka goldfield in Otago. After negotiations with the Maori owners of the land, complicated by the start of the New Zealand Land Wars in Taranaki, the Coromandel area was declared a goldfield in June 1862 (Salmon 1963: 180; Weston 1927: 23). Again, seekers after alluvial gold were disappointed, but this time the quartz reefs were found and hard-rock mining began. In May 1862 Thomas Keven and his partners found a reef near the mouth of the Kapanga River, and floated a company in Auckland to raise money to erect a stamp mill. The machinery was ordered from Melbourne, and it began crushing in January 1863 (Daily Southern Cross, 7 January 1863: 3; 8 January 1863: 3; Salmon 1963: 180). Other mining companies soon erected more stamp mills, although a number of factors, including the outbreak of the war in the Waikato in the autumn of 1863, restricted development (Weston 1927: 23).

The main focus of Hauraki quartz mining development in the late 1860s was around Thames. Again, the Waikato war slowed development, and negotiations with local Maori were necessary for access to the land, but on 1st August 1867 the Thames Goldfield was opened (Thames Miner’s Guide 1868: 67; Weston 1927: 29-35). The first battery to be set up on the Thames field was the Great Expectation, a four-stamp mill with wooden stamps shod with iron (see Figure 18 in Chapter 3), and by the end of 1868 some 27 batteries were working (Salmon 1963: 185; Thames Miner’s Guide 1868: 93).

The discovery of the Thames reefs compelled official acknowledgement that the small claim areas allowed for alluvial mining were not suitable for quartz mining, and much larger leases were allowed from 1869. Capital investment was encouraged by the imposition of an additional rent unless machinery was installed (Salmon 1963: 103, 187; Weston 1927: 63). One of the most notable aspects of the Thames field was its ‘bonanza’ strikes, where patches of exceptionally rich stone were encountered. For example, at the Caledonian Mine (Figure 27) between May 1870 and June 1871 some 139,577oz. of gold were won, and for the 1871/72 financial year the mine paid dividends of £560,889/10- (Salmon 1963: 188, Weston 1927: 69).

Figure 27. “The famous Caledonian Mine” (Weston 1927).

One effect of finds like this was to encourage the amalgamation of small mining companies, which allowed more resources to be directed at developing the mines and building large stamp mills. The 40-stamp Moanataiari Battery was the largest in Australasia when it was built (Salmon 1963: 190). The use of this type of heavy machinery, together with the presence of engineering companies such as A.&G. Price, gave Thames a particularly
industrial character, accompanied by the constant pounding of the stamp mills: at one time 693 heads of stamps were at work in the local mines (Weston 1927: 70).

A short distance further south from Thames, the Ohinemuri field was opened in 1875 with a rush more akin to the Hollywood stereotype than anything that had happened in Otago in the 1860s. This area had been closed to prospectors because it was Maori land and no access agreement had been reached with the chief Te Hira (Salmon 1963: 241). There was therefore an enormous degree of pent-up expectation when the field finally was due to be opened on 3 March 1875. As the Warden declared it open there was a mad rush to peg out claims:

About 9.55 a.m. Warden Fraser mounted an improvised platform, and, after a brief address, read the proclamation declaring the field open for gold-mining. The struggle to obtain the miner’s rights, followed by the helter-skelter down the hill, across the Ohinemuri River and then up the opposite bank, can better be imagined than described. Just picture eight hundred excited men starting all together from one place at a given signal, the track going down a steep bank, across a mountain-torrent, and thence up another abrupt incline, the goal being the Prospectors’ Claim at Karangahake…. When crossing a good number measured their lengths in the stream, and those were converted into temporary stepping-stones by others comprising the rear-guard who were fortunate enough to retain their footing. (McCombie 1897: 34)

Despite the drama of this scramble for claims, the initial result was disappointment because once again easily-workable alluvial deposits were not found, and it would be the hard-rock mines of this area that would prove profitable once the cyanide process was introduced in 1889 (Salmon 1963: 243).

Mining at Waihi started relatively late and slowly, but would become the location for New Zealand’s largest gold mine. The Martha Reef was discovered by Robert Lee and James McCombie in 1878 but for many years defied profitable extraction due to the very high losses of gold through the batteries (McAra 1988: 28, 48). As experience would prove, the Martha Mine had a vast low-grade but uniform reef system, which would pay only if worked in a systematic and efficient manner. The London-based Waihi Gold Mining Company did just this starting in 1887 (this company is discussed further below).

In 1880 Hone Werahiko found gold in the Waiorongomai Valley, in an exposed reef later called the ‘Buck Reef’ (Henderson & Bartrum 1913: 13). Josiah Firth and James Clark purchased the Piako Battery at Thames and moved it to the mouth of the Waiorongomai Valley in 1882/83 to process ore from the various claims in the valley (Moore & Ritchie 1996: 177; Weston 1927: 71). In order to transport ore from the mines to the battery the Piako County Council constructed a three-mile tramway in the valley at a cost of £19,000, of which £9,000 was provided by the Government (Henderson & Bartrum 1913: 14). This tramway included three self-acting inclines, where descending fully-laden ore carts pulled up empty carts via a cable and winding drum located at the top of each incline (Figure 28). The Waiorongomai mines failed to live up to expectations, but the tramway system illustrated how the development of quartz mining fields did not just involve expensive mining machinery, but at times equally or more expensive infrastructure development.
On the West Coast and Nelson the exhaustion of the easily won alluvial gold in the mid 1860s led to the active search for quartz reefs. In Nelson the first major discovery (the ‘Perseverance’) was at Bedstead Gully near Collingwood in 1866, and the first stamper battery on the Coast was erected at Moonlight Creek in 1868 (Johnston 1992: 439-441; Salmon 1963: 162). The Lyell quartz field was discovered by Antonio Zala in 1869, and the United Alpine Company started work there in 1874 (Salmon 1963: 162). The main centre of quartz mining on the West Coast was the Inangahua field centred on Reefton. The first quartz reef in the area was discovered in 1870, and by the end of the year five distinct series of reefs had been found between the Inangahua and Waitahu Rivers (May 1969: 53; Salmon 1963: 163). In 1871 a syndicate formed by Richard Shiel erected a steam-powered battery on Murray Creek, and by the middle of the following year some 50 mining claims had been registered (Salmon 1963: 163). Discoveries of new reefs in the wider area continued for some years, including Big River in 1880 and the Alexander River as late as 1920 (Bolitho 1999: 75-88; Salmon 1963: 165; Wright 1993). Further south, gold-bearing quartz was found in 1884 at Cedar Creek near Ross, and 40 mining leases were taken out in the area (May 1969: 67).

In Otago the first quartz mine was at the Shetland Reef near Waipori. In March 1862 a quartz reef was discovered and prospected by six men who had previously been in Victoria, but they abandoned the ground as it was too difficult to work (Otago Witness, 5 July 1862: 5). In July Hosea Fraser and Andrew Williamson applied for a prospecting claim on the reef, and the newly-formed Otago Quartz Mining Company had a 4 stamp battery and water wheel in operation by January 1863 (Otago Witness, 26 July 1862: 5; OPC V&P Session XVII 1863: 16). This was soon replaced by a ten stamp battery imported from Melbourne, and by 1864 three other mills were in operation in Otago at the Skippers and Elgin Reefs (Upper Shotover) and Arrow Reef (Arrow) (OPC V&P Session XIX 1864: 12-13).

As a comparison, at this time when the first four-stamp battery in Otago was in action, the Otago Witness reported from the Victorian mining statistics for July 1863 that “in quartz reefing there are employed 449 steam engines of 7,950 horse power, 53 crushing machines, 195 whims and pulleys, 28 water wheels, 3 derricks, and 59 whips” (Otago Witness, 22 September 1863: 5). There was therefore a well-established Australian industry upon which New Zealand could draw.
The Era of Industrialisation

The last year in which gold constituted more than half of New Zealand’s export value was 1871, and events such as the introduction of refrigerated shipping in 1882 steadily increased the significance of the farmer to the nation’s income (King 2004: 237-238; Salmon 1963: 209). Towards the end of the nineteenth century the easily-won alluvial gold was gone, and the shallow reef systems that could be worked by small partnerships were worked out. While there were always exceptions, this was the period where large companies and overseas investment became important. The gold mining industry came to depend on three technological innovations: the cyanide process of gold extraction in the battery, the bucket dredge in rivers and on alluvial flats, and the hydraulic elevator in sluicing claims (Salmon 1963: 210). Of these, it is the cyanide process that concerns us here.

The Cyanide Process

Most of the early batteries were highly inefficient, and a great deal of gold was lost in the tailings. In 1896 Warden Dalgleish of Naseby commented “in numbers of our previously-worked quartz mines more of the gold was lost during the process of crushing than was actually saved” (AJHR 1896 C3A: 22). The introduction of the cyanide process in the late 1880s probably did more than any other innovation to answer this criticism, and it was widely adopted around New Zealand and the world.

It had been known since the Middle Ages that cyanide solutions could dissolve gold, and gold had been recovered from ore by using potassium cyanide solution in the 1860s (Eissler 1894: 42; ILT 1902 S31: 1). Experimental work was also carried out in New Zealand, and in 1886 William Skey reported on experiments at the Colonial Laboratory on a sample of stone from Waihi (AJHR 1887 C5: 62). But it was the development of the practical McArthur-Forrest treatment that made it a viable commercial process (Jack 1984: 24). Three Glaswegians, John MacArthur and brothers Robert and William Forrest, had formed a syndicate in 1885 to research gold extraction using cyanide solutions, and their work came to the notice of Sir Charles Tennant who owned the Cassel Gold Extraction Company. Tennant approached MacArthur to work for the Cassel Company, with the understanding that the MacArthur/Forrest syndicate would continue their own work on cyanide, and if this was successful the Cassel Company would have first option for the purchase of the rights to the process. By 1887 the process had been proven to be effective, and a series of patents were taken out in 1887 and 1888 (Birrell 1998: 132; Todd 2009: 115-117).

New Zealand was a very early adopter of the process, and the first large-scale field trial was carried out in 1889 at Karangahake. An initial small trial plant was erected in the Woodstock furnace house and a full-sized plant was erected near the Crown Company’s battery. The trial plant went into operation in July 1889, treating ore from a number of local mines, and the main cyanide plant probably started work in January 1890 (McCrombie 1897: 35; Te Aroha News, 27 July 1889: 2; Thames Star, 24 September 1889: 2; 27 September 1889: 3; Waikato Times, 26 September 1889: 2; 28 January 1890: 3; 11 March 1890: 2). Despite some initial setbacks the cyanide process soon showed its promise, but it was very expensive to use because of the royalties charged by the Cassel Company, which were 10% on all ore up to the value of £8 per ton, and 15% on all ore over that value (AJHR 1981 C4: 35). This effectively meant that the process could only used on ores that had an assay value of £2 per ton or more, and put it out of the reach of many smaller mining companies. To address this issue, in 1897
the Liberal Government bought the New Zealand patent rights to the cyanide process for £10,000 and passed the *Cyanide Process Gold Extraction Act*, which enabled mining companies to use the process for only half the previous fee (Gordon 1906: 462; Ritchie 1990: 38; Salmon 1963: 214, 252). The technical details of the process are described in more detail in Chapter 6 below.

**Overseas Capital**

A restrictive factor in the New Zealand quartz mining industry was that the local companies had been too small and their capital too limited to deal effectively with large but poor quality ore bodies, which needed to be worked efficiently on a large scale to be profitable. In the late 1880s and 1890s the attention of British investors began to turn to the world’s goldfields, stimulated by a number of factors including the expansion of the Rand and West Australian goldfields and the development of the international telegraph network that allowed mining information to travel quickly (Blainey 1993: 97; Mate 2010: 294; Salmon 1963: 219). Salmon (1963: 220) observed that “it became the custom for New Zealand promoters to make a pilgrimage to London to attract capital.” Many local goldfields were revived by British capital, including Reefton through David Ziman’s Consolidated Goldfields syndicate (Gage 1948: 34; Latham 1984: 300), and Macetown through W.J. Farrell and New Zealand Consolidated Gold-mines (AJHR 1905 C3: 58).

London money was behind New Zealand’s largest historic mining operation, that of the Waihi Gold Mining Company. Between 1887 and 1891 the Company acquired the Waihi mines, reconstructed and expanded the batteries, and experimented with better gold-recovery processes. The Company sent its new manager, J.W. (‘Long Drive’) Walker, to study American battery practice, imported new processing machinery and later adopted the cyanide process of gold extraction (McAra 1988: 53-54). By 1906 the Company had completed its 200 stamp Victoria Battery, which was the largest stamp mill ever built in New Zealand (Galvin 1906: 356). To power its vast operation in 1910-13 the Company built at what was at the time the largest hydro-electric power station in New Zealand at Horahora on the Waikato River (McAra 1988: 143; Rowe & McKey 1997).

**The Twentieth Century: War & Depression**

By the turn of the twentieth century gold mining had been well established as one of the country’s leading industries for some decades, but as already mentioned above, it had ceased to provide more than half of the national export earnings in 1871, and the agricultural sector had become increasingly more important to the economy. One Mines Inspector observed in 1912 that:

> In both the Thames and Coromandel Counties mining is slowly being superseded by agriculture. Dairy-factories have been established, and the occupation of the people formerly engaged in mining is undergoing a gradual change. The same feature is observable in many other of the older mining-fields of the Dominion which are approaching depletion- notably on the West Coast, in Otago, and in Southland. (AJHR 1912 C2: 22)

The most significant global events of the first half of the twentieth century were two World Wars and the Great Depression, all of which had significant and complex effects on the
mining industry. One very clear effect was on labour, of which there was a shortage during wartime and a glut during the depression, but there were also more complex economic effects as the demand (and therefore price) of different commodities changed and the state became more actively involved in the industry.

Many mines reduced their output and development work during the 1914-18 and 1939-45 because they lost so many men to the armed forces. During the First World War the Minister of Mines announced that no other industry had had such a response to the call to arms, and this reduction in the workforce combined with the rising price of cyanide (which was imported from Germany before the war) led to the annual gold production falling to close to half of its pre-war total (Ritchie 1990: 31; Salmon 1963: 265). The Second World War saw a similar loss of mining labour, and many mines were either shut down or put most development work on hold (AJHR 1944 C2: 16; 1945 C2: 16; 1946 C2: 29). By this time many of the known gold deposits were also becoming exhausted, and the lack of development work meant it was not economic to reopen them after the war. In addition many men did not return to mining when peace came (AJHR 1947 C2: 26).

A second effect of the wars was on the prices of certain commodities. Scheelite is an ore of tungsten, which is used for hardening steel and so was greatly in demand for armaments manufacture during both World Wars. In several places in Otago, notably Macraes Flat, Glenorchy, Barewood, Waipori and Bendigo, gold and scheelite were found together and could be processed using the same methods and machinery. Their relative prices tended to dictate which was sought in these fields at different times, and during wartime mining activity focussed almost solely on scheelite (AJHR 1917 C2: 34). During the Second World War the Mines Department itself took over two of the principal scheelite mines in the Glenorchy area to ensure an increased and balanced production (AJHR 1943 C2: 7).

Between the two World Wars, the Great Depression of the early 1930s created in some ways the opposite labour situation to that of wartime. The usual estimate for the peak number of unemployed in New Zealand is about 80,000 in July 1933, but if women, youths and the under-employed are included the estimate can be as high as 240,000 (King 2004: 347; Rankin 1994). One of the initiatives to provide some relief for unemployed men was a mining subsidy provided under Unemployment Board Schemes, the first of which was established in 1931 (Salmon 1963: 271). Many abandoned mining fields were again populated; for example, for the 1932 year the annual Mines Inspector’s report on the Southern Inspection District stated that:

Kawarau Gorge, Cromwell, Bannockburn, Bendigo, Luggate, Clutha, Clyde, Waikerikeri, Blackman’s, Conroy’s, Matakanui, Drybread, Devonshire, Cardrona, Matatapu, and Lindis- Four hundred and thirteen men were engaged fossicking, prospecting, sluicing, elevating, driving and sinking. (AJHR 1933 C2: 35)

The following year some 714 men were working in the same area (AJHR 1934-35 C2: 37). The West Coast was a scene of a particularly large resurgence, and in 1933 some 1,907 men were recorded as being employed mining there (excluding the men employed in some of the mining companies) (AJHR 1934-35 C2: 32). The majority of these men were seeking alluvial gold, where mining could be carried out without capital, and the resurgence in hard-rock mining was far more limited. Nevertheless, as the Depression continued through the mid-1930s increasing interest was paid to hard-rock fields, and in 1934 the Unemployment Board instigated a lode-prospecting scheme (AJHR 1935 C2: 41; 1938 C2: 33). Certain economic
factors favoured this resurgence other than simply the need to generate employment. In particular the abandonment of the gold standard meant that the price of gold rose from about £3 15s. per ounce in 1931 to £8 4s. in 1934 (Salmon 1963: 270, 274). The number of men employed in gold mining peaked at 6,715 in 1935 (Lloyd Prichard 1970: 346), and then decreased in the late 1930s as the Depression waned, and the declaration of war in 1939 changed the labour market again.

The Last Mines & The Resurgence

Just as the easily won alluvial deposits had soon been worked out during the rush years, the underground reef systems were not inexhaustible. By the 1910s the Thames field, known for its earlier bonanza strikes, was winding down, and in September 1913 water and gas broke into the last low-level workings, pumping was abandoned, and all levels below the surface were left to flood (Weston 1927: 120). An attempt to reopen some of the Thames mines in the early 1920s yielded only 362oz. of gold, and the last mine at Thames, the Sylvia, finally shut down in 1947 (Salmon 1963: 267, 279). At Macetown in Otago various attempts to reopen the mines failed to be profitable, and the large Homeward Bound Battery was last used sometime between 1914 and 1920 before being abandoned on site. Some efforts to prospect the field in the 1930s came to little (AJHR 1935 C2: 41; 1937 C2: 46). Big River, near Reefton, survived until the Second World War, but shut in 1942 and never reopened (Wright 2004: 38). Similar stories applied to many hard rock mines throughout this period, with the combination of dwindling resources and labour difficulties proving fatal.

Two of the leading mining companies in New Zealand survived until the 1950s, when they too shut down, bringing the end of an era. The Blackwater Mine at Waiuta weathered the labour shortages of the war and still had proven ore reserves when one of the main shafts collapsed in July 1951, bringing about the sudden total closure of the mine (AJHR 1952 C2: 38). The end of the Martha Mine\(^6\) at Waihi was not as catastrophic, but was just as final, as the known reserves were worked out and the decision was made to cease operations in 1955. The Inspector of Mines J.B. McAra wrote in his 1956 report:

Martha Gold Mining Co. (Waihi) Ltd. The company ceased to have a place of business in New Zealand on 9 July last, thus signifying the official conclusion of the life of the Martha Mine as one of the former great gold producers of the world.

(AJHR 1956 C2: 42)

By the mid-1950s hard rock gold mining was at a virtual standstill in much of New Zealand. Only a few small players were still working, such as John and Pat Lillis in the Coromandel (Salmon 1963: 279). Prospecting did continue in some areas, and new technology was available that would have been unthinkable to the subsidised miners working by hand only twenty years earlier; for example in March 1958 a helicopter was used to fly a diamond drill rig into the headwaters of the Taipo River in Westland, an area previously only accessible on foot (AJHR 1959 C2: 43). The post-war availability of earth-moving machinery such as small bulldozers also began to change the face of what survived of the mining industry, as both access road construction and open cast mining became easier.

---

\(^6\) Due to taxation issues the Waihi Mining Company had been split into three entities in 1935, and the Martha Gold Mining Company was one of these (Salmon 1963: 274).
Some small companies did start up in this period, such as the Consolidated Silver Mining Company that set up a new processing plant at the site of the old Maratauto battery in the late 1960s (Bale 1971; Moore & Ritchie 1996: 128), but the real resurgence of hard rock mining came in the late 1980s as rising gold prices fuelled interest in the old deposits. In 1987 the New Martha Hill Mining Company began opencast mining at Martha Hill, previously the location of the underground Waihi Mining Company’s Martha Mine. In 1990 Cyprus Minerals started opencast and underground operations at Golden Cross in the Waitekauri Valley, and in the same year Macraes Mining Company began opencast mining at Round Hill in Otago. At the time of writing (2013), the Golden Cross Mine had closed but Oceana Gold (the present owners of the Macraes Mine) have mines at Macraes Flat and Globe Hill (Reefton) and Newmont Gold is working both opencast and underground mines in Waihi.

These modern mining companies are working gold deposits that were mined in the past. Their profitable re-working is due to modern mining methods whereby very large amounts of low-grade ore can be mined, moved and processed in bulk using heavy earth-moving machinery. There are still a few small-scale mines, such as at Broken Hills, but generally modern hard rock gold mining in New Zealand consists of a few very large highly mechanised operations.

**Summary of New Zealand and the 19th Century Rushes**

From the above discussion, several main themes can be identified, amongst which are three that are important to this thesis: chronology, technology and administration.

As discussed at the start of the chapter, the almost clichéd sequence of California-Australia-New Zealand gold rushes (1840s-1850s-1860s) does hold true, but there was also an on-going and complex series of subsequent rushes (and even counter-rushes) throughout the 1850s to 1880s that meant that there were major overlaps between the lives of these goldfields, and there was a great deal of movement of people and ideas between the different areas. What was important in the initial sequence, especially for New Zealand, was that by the 1860s there had evolved experience in both mining techniques and goldfield administration. New Zealand hit the ground running.

Critical to this thesis, the technology of gold mining in each new goldfield was affected by the experiences of the previous rushes, and then continued to benefit from cross-pollination of people, ideas and machinery. Each rush consisted of some men with, and many men without, mining experience, but generally the techniques of gold working were transferred from place to place, adapted and selected to suit local conditions. As each rush was replaced by a more permanent mining industry, and the machinery-dependent quartz mining commenced, there was an on-going flow of information to- and fro- between the major mining fields and manufacturing concerns. As already discussed in Chapter 3, New Zealand mining companies imported machinery from Melbourne from the very outset of local hard-rock mining. As overseas capital became involved this affected the choices of technology and manufacturers. A major change in many late nineteenth century mining areas, including New Zealand, was the transition from traditional ‘selective’ mining, whereby skilled miners worked rich lodes, to ‘mass production’ mining using sophisticated mining and processing technology to work large low-grade ore bodies (Burt 2000: 322). Technological development was therefore central to the on-going profitability of mining, and its effect can be seen in the increase in gold production in New Zealand in the 1890s and 1900s (Figure 29).
New Zealand also benefitted from the accumulated experience in how to administer goldfields. Despite the major difference in philosophy between the US and the British Colonies regarding Crown (state) ownership of gold, the experiences of running a goldfield were cumulative. The Californian rushes occurred before there was an effective administration in place whereas in Australia and New Zealand the civil administration was already functioning when the diggers arrived. Because of the Australian experiences, and particularly the mistakes that culminated in Eureka, the administration of the New Zealand goldfields was made much easier and smoother: “New Zealand profited by the examples of Australia and California while maintaining peace and order in a way that Australia had not done and California had not even thought of” (Fetherling 1997: 78).

**Figure 29. Gold production of New Zealand from 1860 until 1965 (Williams 1965).**
Chapter 5
The Anatomy of a Stamper Battery

All forms of gravitation stamp mill operated by the same basic principles, and as such had the same basic parts, which can be summarised within four main groups (Figure 30):⁷

1. The frame
2. The mortar
3. The lifting mechanism
4. The stamp

Figure 30. The four main ‘groups’ in the stamp mill structure.

---

⁷ This is adapted from Louis (1902: 122). Most contemporary authors separated the stamp-mill into similar units or groups for discussion.
Group 1: The frame consisted of the timber or iron framework that supported the camshaft, lineshaft (also called the countershaft) and stamp guides, and therefore had to also support the weight of any stamps that were being lifted by the camshaft.

Group 2: The mortar included the mortar box, together with its screens and other attachments, and the mortar block or baulk which formed its foundation. In wooden framed batteries the mortar box foundations and the stamp frame foundations were usually separate structures in order to isolate vibration.

Group 3: The lifting mechanism consisted of the camshaft and cams and the drive wheel on the camshaft, together with the camshaft bearings.

Group 4: The stamp consisted of a stem, a head with a removable shoe, and a tappet.

Although the basic function of these parts remained the same as the form of the mill evolved, the detail of design and operation of these parts changed greatly during the second half of the nineteenth century, and a large theoretical and practical body of knowledge was built up regarding almost every single individual element. Extensive experiments were at times carried out exploring the effects of small design alterations on stamp mill productivity (eg Caldecott 1909; Morison & Bremner 1900: 157-164). From the time the Californian stamper was developed in the 1850s until it was superseded by the ball and tube mills in the early decades of the twentieth century its design was constantly changing in detail; some of these changes were effective, some less so, and some simply reflected differences between manufacturers. As Morison & Bremner (1900: 159) pointed out: “The commercial requirement is reform, not revolution. An enormous amount of capital is invested in cam-stamp mills, and it is highly desirable that any improvement in fine-crushing machinery should be applicable to existing mills, without necessitating radical and expensive structural changes therein.” Therefore, much change was incremental.

**Terminology**

There was a standardised terminology for the parts of a stamp mill, albeit with some variation. Some of this variation was probably national, illustrated by the three Figures (31 to 33) below; Richards (1906) was an American publication, while Truscott (1923) was British. Table 1 summarises the main technical terms and some of the main differences that have been noted. In addition to these main elements, there were also other items such as a power supply required for a battery (see Chapter 6), together with numerous small fixtures and fittings (Figure 34).
Figure 31. An isometric view of a ‘back-knee’ frame battery showing the basic terminology according to Richards (1906), an American source.
Figure 32. Front elevation of a ‘back-knee’ frame stamper battery showing terminology according to Truscott (1923), a British source.
Figure 33. Side elevation of a 'back-knee' frame battery showing contemporary terminology according to Truscott (1923).
Table 1. Battery terminology.  
Showing variations in terms used between various sources. Truscott (1923) is a British source, Richards (1906) is American and Gordon (1906) is the main New Zealand text. Other variations are noted, with the sources identified in the footnotes.

<table>
<thead>
<tr>
<th>Truscott (1923)</th>
<th>Richards (1906)</th>
<th>Gordon (1906)</th>
<th>Other variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud sill</td>
<td>Mud sill</td>
<td>Mud sill</td>
<td></td>
</tr>
<tr>
<td>Streak sill</td>
<td>Cross sill</td>
<td>Cross sill</td>
<td>Battery sill&lt;sup&gt;9&lt;/sup&gt;</td>
</tr>
<tr>
<td>Battery post/King post</td>
<td>Post</td>
<td>Battery post</td>
<td></td>
</tr>
<tr>
<td>Mortar block binder</td>
<td>Buckstaff</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortar block</td>
<td>Mortar block</td>
<td>Mortar block</td>
<td>Battery block&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Top guide</td>
<td>Upper guide timber</td>
<td>Guide</td>
<td></td>
</tr>
<tr>
<td>Bottom guide</td>
<td>Lower guide timber</td>
<td>Guide</td>
<td></td>
</tr>
<tr>
<td>Battery post binder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortar box</td>
<td>Mortar</td>
<td>Mortar</td>
<td>Battery box&lt;sup&gt;10&lt;/sup&gt;, Coffer&lt;sup&gt;21&lt;/sup&gt;</td>
</tr>
<tr>
<td>Screen</td>
<td>Screen</td>
<td>Screen</td>
<td></td>
</tr>
<tr>
<td>Die</td>
<td>Die</td>
<td>Die</td>
<td></td>
</tr>
<tr>
<td>Shoe</td>
<td>Shoe</td>
<td>Shoe</td>
<td></td>
</tr>
<tr>
<td>Head/boss</td>
<td>Boss</td>
<td>Stamp head/socket</td>
<td>Boss-head&lt;sup&gt;11&lt;/sup&gt;</td>
</tr>
<tr>
<td>Stem</td>
<td>Stem</td>
<td>Stem/stamp shank</td>
<td>Shank&lt;sup&gt;13&lt;/sup&gt;, stalk&lt;sup&gt;14&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tappet</td>
<td>Tappet</td>
<td>Tappet</td>
<td>Stud&lt;sup&gt;15&lt;/sup&gt;, disc&lt;sup&gt;16&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cam shaft</td>
<td>Cam shaft</td>
<td>Cam shaft</td>
<td></td>
</tr>
<tr>
<td>Cam shaft bearing</td>
<td>Cam shaft box</td>
<td>Plummer block or Cam shaft bearing</td>
<td>Cam-box&lt;sup&gt;17&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cam</td>
<td>Cam</td>
<td>Cam</td>
<td>Wiper&lt;sup&gt;18&lt;/sup&gt;</td>
</tr>
<tr>
<td>Driving-pulley</td>
<td>Pulley</td>
<td>Battery pulley</td>
<td>Bull-wheel &lt;sup&gt;19&lt;/sup&gt;, Cam-shaft pulley&lt;sup&gt;20&lt;/sup&gt;</td>
</tr>
<tr>
<td>Belt tightener</td>
<td>Tightener</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>8</sup> Louis 1902: 234  
<sup>9</sup> ILT 1902: 36  
<sup>10</sup> Phillips (1867): 173  
<sup>11</sup> Ulrich (1875): 66  
<sup>12</sup> Del Mar (1912): 30  
<sup>13</sup> Ulrich (1875): 66  
<sup>14</sup> Otago Witness (18 June 1864): 16  
<sup>15</sup> Phillips (1867): 174  
<sup>16</sup> Otago Witness (18 June 1864): 16  
<sup>17</sup> Del Mar (1912): 29  
<sup>18</sup> Ulrich (1875): 66  
<sup>19</sup> Del Mar (1912): 29, 72  
<sup>20</sup> Mining & Smelter Supply Co. (1912): 147  
<sup>21</sup> International Library of Technology (1902): 25
SPECIFICATIONS FOR A TEN-STAMP GOLD MILL

AMALGAMATING

1 Grizzly or Ore Screen, 4 x 10 ft.; 1 Blake Crusher, 10 x 7 in.; 2 Ore-Bin Gates, 18 x 24 in.

2 Automatic Ore Feeders, standing or suspended type.

All necessary bolts and washers for ore bins.

1 Ten-Stamp Mill of 1000 lbs. each stamp; arranged to run in one battery driven by belt and tightening from stamp countershaft; as follows:

2 High Mortars of latest improved design, having screen frame seats machined, and foundation bolt holes drilled to template and bottom plates planed. Arranged for inside amalgamation, and fitted with removable linings. 2 Sets of hard iron liners for sides and ends of mortar. 2 Wood Screen Frames with Keys and fitted to mortars, with extra screens. 1 Set of three sizes of wooden chuck blocks and holding keys for equalizing depth of the discharge. 10 Stamp shoes and dies of forged or Chrome steel. 10 Cast iron stamp heads, bored for stems on one end and recessed for shoe necks. 10 Stamp stems of steel, tapered both ends. 10 Cast or Chrome steel 3-key tappets, with gibbs and keys. 2 Feed tappets in halves. 10 Chrome steel cams with Canada fastenings, fitted to cam-shaft. 1 hammered iron cam-shaft, with open type boxes and steel collars. 10 Stamp fingers, with shafts, boxes, and sockets, complete. 1 Cam-shaft pulley of wood, with iron center, turned and painted, keyed to cam-shaft. 1 Set (2) of standard solid hard wood guides, bored for stems, and provided with guide bolts, nuts and lock washers. 2 Mortar pads of 1/4 in. rubber packing. 1 set of water spray pipes for 10 stamps, with valves and fittings, and rubber hose for washing plates. 1 Set of bolts, rods, nuts and washers, with lock washers for framework for 10 stamps, including foundation bolts and washers for mortars.

Inside plate copper 1/8 in. thick for lining mortars and mortar lips. 2 Sheets Copper 54 in. x 96 in. x 1/6 in. thick for tables in front of mortar, all silver plated with one ounce silver per square foot of surface.

1 Belt Tightener, complete. All Shifting, Pulleys, Bearings and Belting, necessary for driving all of the above described machinery in accordance with our plans. Water pipe as specified. 1 Overhead Crawl, with track iron, and chain block.

1 Stationary Slide-Valve Steam Engine, of proper size, as may be specified.

1 Horizontal Tubular Steam Boiler, of proper size, complete, with all fixtures and trimmings, breeching and smoke stack, as may be specified, including boiler-feed pump, injector and heater.

All pipes, valves and fittings for steam, exhaust and water to make power plant complete, as per plans furnished.

Setting plans and Battery frame drawings are supplied to enable millwrights to erect the mill.

Figure 34. The Mine & Smelter Supply Company (1912) list of parts for a 10 stamp battery.
The usual ‘module’ of a stamp mill was five stamps, although 1, 2, 3, 4 and 6 stamp batteries did exist. In general, the size of battery could be increased by simply duplicating the mill equipment, and so 10, 15 and 20 stamp mills were simply made by building 2, 3 or 4 sets of five stamp modules together (Figure 35). The largest example of this in New Zealand was the 200 stamp Victoria Battery built by the Waihi Mining Company at Waikino near Waihi (Galvin 1906: 356). Thus, many of the technical details below apply equally to virtually any size of stamper battery, from a single stamp to 200 stamps.

Figure 35. The Keep it Dark Battery near Reefton (Galvin 1906).
Technical Descriptions of Stamp Mill Parts

Group 1: The Frame

The frame was generally constructed of either timber or of iron, and had to be capable of withstanding both the static and dynamic loads of the stamp mill. Most mills had substantial below-ground foundations designed to support both the weight of the machinery and the considerable vibration generated when it was in operation. There were, in fact, two independent structures in most mill frames: the mortar blocks that supported the mortar boxes; and the sills, battery posts and braces that supported the camshaft, stamp guides and any stamps that the camshaft was lifting. The reason that they were separate was to isolate the upper framework from the considerable vibration that could affect the mortar blocks (Phillips 1867: 174). The mortar foundations are discussed below in Group 2.

There were several exceptions to this practice of having two separate structures. Early Californian mills had a single timber frame structure, and when a mill was to be built on marshy or ‘unreliable’ ground, a horizontal mortar block was sometimes used, set across the structure of mud and cross sills (Richards 1906: 148). But the main exception was when concrete was adopted for stamper (particularly mortar block) foundations from about the turn of the twentieth century. When concrete was used the vibration problems were largely overcome due to the inertia of its mass, and the upper framework could be mounted on the same foundation (Truscott 1923: 143-144, 147).

The Lower Framework: Mud Sills & Streak (or Cross) Sills

Tinney (1906: 186) commented that “it is well to emphasise the fact that the soul of the mill lies in its foundations, and that its life and total output depend on the care bestowed on this important and hidden part of the work.” The underlying framework of a stamp mill consisted of large timber beams (termed ‘sills’) (Figure 36).

Figure 36. A stamp mill with the main foundation structure shaded (adapted from Richards 1906).

The lower framework would usually be buried. The bottom layer, running parallel to the axis of the mortar boxes and camshaft, were the mud sills. Above the mud sills, and running perpendicular to them, were the cross-sills or streak-sills, which were checked about 2 inches deep into the mud-sills, the two then being bolted together at each joint (Louis 1902: 234). The numbers of mud sills depended on the weight of the battery and the ground conditions, but generally there were three or four, and occasionally six (Richards
1906: 152). The number and location of the streak-sills were limited by the spaces on either side and between the mortar boxes: a 5 stamp battery would have two streak-sills, a 10 stamp battery would have three, and so on. There could be several layers of mud and cross sills, depending on the ground conditions.

The sills were generally very large timbers, even for reasonably small batteries, as they had to both support the battery structure and absorb vibration. Gordon (1906: 375) stated that the mudsills should be 12 by 14 inch timbers, the *International Library of Technology* (1902: 26) commented that the sills were usually of 12 inch square timbers, while Richards (1906: 153, Tables 83, 84) gave a range of 12 by 12 inch to 24 by 24 inch mudsills and 12 by 16 inch to 18 by 24 inch cross (streak) sills.

When horizontal mortar beams were used the sill structure would often be heavier than normal, and the mortar box and the battery posts were mounted on the same beam. Richards (1906: 148) stated that in the Dahlonega District of Georgia this was a common method of construction (Figure 37), and it was also used in a mill in Gilpin County, Colorado, where it was found that the long stamp drop onto vertical mortar blocks gave trouble by breaking stamp stems.

![Figure 37. The Hall Stamp Mill, Dahlonega District, Georgia, America (Richards 1906).](image-url)

When concrete began to be used for stamper foundations, and in particular for mortar blocks, it was found that the platform of sills could be modified, or even dispensed with altogether (Truscott 1923: 147). In this case, a single concrete foundation would support both the mortars and the battery frame (Figure 38). The use of concrete mortar block is discussed in more detail below.
Figure 38. A ten stamp back-knee battery shown with timber or concrete foundations (The Mine & Smelter Supply Co. 1912).
The Upper Framework: Driving, lifting, feeding & guiding

The upper framework of a battery had several roles to play, including supporting the camshaft and guiding the rising and falling stamps. In some battery designs it was also part of the structure that supported the ore bins and the feeder floor where ore feeders or men with shovels stood. There was considerable variation in the layout of this superstructure, and two main materials were used; timber or iron (Richards 1906: 152).

Timber Frames

The greatest degree of variation in design occurred in timber framed batteries. The main variable was the way that the upright timber supports for the camshaft and stamp guides were designed and braced. The direction from which the drive to the camshaft was taken was an important factor in designing the bracing, because the drive belt had to be tensioned to transmit power, which imposed a sideways load on the frame. Line- or intermediate-shafts could be mounted on the cross-sills, or on structures fore or aft of the camshaft (Louis 1902: 231). Another important feature was whether the ore bin structure was constructed as part of the stamper structure, which was a common practice in many heavier batteries, although some authorities disapproved as the settling of the ore bin could throw the mill frame out of line (F.S. Phebe, cited in Richards 1906: 158). Taking into account all of the variables, it is probably true to say that while many batteries bore similarities to each other, few were ever exactly alike.

Several authors divided battery frames into two general classes: the A-frame and the knee-frame (International Library of Technology 1902: 24; Louis 1902: 234; Richards 1906: 157). In most contemporary discussions both of these forms used vertical battery- or king-posts, with the form of the bracing determining the overall class. A-framed batteries used diagonal braces from the battery posts to the cross-sills, and were generally used for light stamps under about 750lb (Louis 1902: 234; Richards 1906: 158). Knee-framed batteries used horizontal members (the ‘knees’) fore or aft of the battery post. These various forms are illustrated in Figures 39, 40 and 41. As can be seen in the illustrations, hybrid forms with both horizontal and diagonal braces were also possible.

A significant variation on the A-frame battery is illustrated in Del Mar (1912: Figure 25) which did not have a vertical battery post, but simply two heavy diagonal posts (Figure 42), and could be considered to be a more pure form of an A-frame. In this frame the legs of the ‘A’ are the battery posts and did not require additional bracing, while in the other A-frame batteries illustrated here the legs of the ‘A’ are braces supporting a conventional battery post. Another frame variation was the double-post frame, which used pairs of battery posts (Del Mar 1912: 73, 76). A small version of this frame type manufactured by the Joshua Hendy Machine Works is illustrated below (see Figure 47).
Figure 39. Battery frame variations from Richards (1906).
Figure 40. Battery frame variations from Richards (1906).
By the beginning of the twentieth century the knee-frame was rapidly replacing the older A-frame form (Del Mar 1912: 73; *International Library of Technology* 1902: 24; Louis 1902: 234), and several authors discussed only knee-frames (e.g. Truscott 1923: 147). In the standard New Zealand reference, H.A. Gordon’s *Miner’s Guide* (1894 & 1906) only a knee-frame battery frame is discussed and illustrated (see Figure 50 below). Furthermore, by 1912 Del Mar (1912: 73) stated that most battery frames being erected were of the back-knee pattern with the ore bin sills being bolted to the battery posts. He considered the front knee-frame, to be weak when used with heavy stamps, and also blocked light from the tables. As an example of how there was not necessarily consensus regarding design, Richards (1906: 158) agreed that back-knee frames were good for the visibility of the plates, but considered that the front-knee frame was the best for heavy stamps.

In common with the foundation timbers discussed above, the size of the battery frame timbers was generally large, 12 by 24 inch section battery posts being common (Gordon 1906: 375;

---

**Figure 41.** Front and side elevations of a 5 stamp A-frame mill (ILT 1902).

**Figure 42.** Cross-section of an ‘A’ frame battery, with the notable lack of a vertical battery post (Del Mar 1912).
ILT 1902: 26; Richards 1906: 153). For batteries with larger numbers of stamps the middle posts were sometimes heavier than the end posts as they carried a greater load. Richards (1906: 153) listed examples of middle posts that ranged from 12 by 24 inches square to 24 inches square, and also commented that a 12 by 24 inch post could be made by combining two 12 inch square timbers. The height of the battery posts was dependant on the height of the overall structure, particularly the stamp stems. Truscott (1923: 145) stated that battery posts were generally 16 to 20 feet in height, and Richards (1906: 153) gave a range of between 19 feet 4 inches and 22 feet 8 inches. These wooden frames were firmly bolted together using a combination of timber braces and iron rods (Richards 1906: 156). Mortised joints were often employed (Louis 1902: 234; Richards 1906: 154).

There were a wide variety of timbers used for the upper frame. Louis (1902: 231) mentioned pitch pine, sugar pine, yellow pine, Oregon pine and Norway pine, and noted that “almost any wood that can be obtained in beams of the large dimensions required may be used.” He observed that Oregon pine was widely exported from America to other countries for battery construction.

Iron & Steel Frames

Iron and steel frames (Figures 43 and 44) were often used in areas where suitable framing timber was scarce and/or where portability was an issue as they could be broken down into small sections for transport (Louis 1902: 321; Richards 1906: 159). They could be built on conventional timber, concrete, brick or stone foundations (Louis 1902: 241).

Contemporary accounts at the turn of the twentieth century state that metal frames were largely used in Australia, with some also in Europe, but were not popular in America and Britain (Louis 1902: 244). Several authors thought that these structures less satisfactory than timber frames because their increased rigidity exacerbated vibration that loosened rivets and bolts, and caused fractures from crystallisation of the metal (Del Mar 1912: 95; ILT 1902: 24; Truscott 1923: 147). Rickard (1898: 144-145) discussed the use of cast iron frames, and in particular the risk of continuous vibration causing the iron to be become crystalline and brittle, but reported that experience at Bendigo, Victoria, with iron framed mills had been successful. Richards (1906: 160) commented positively on metal frames, particularly cast iron, as its use did away with the need for tie-rods and braces, and made a compact frame without the elasticity of steel. Louis (1902: 244) also preferred cast iron frames to steel frames, thinking iron to be
“sufficiently stiff to form a good frame, and elastic enough to stand the jar of the stamps.” He thought that the best design was probably to use hollow castings (Figure 45).

Figure 44. A steel stamp frame manufactured by the Union Iron Works of San Francisco (Richards 1906).

Figure 45. Side elevation of a cast iron framed battery from the Victoria Foundry, Bendigo, Australia (Rickard 1898).

**Portable Batteries**

Small portable batteries were often an exception to many of the designs discussed above. They were designed for prospecting and development work, and were self-contained and easily erected. They therefore did not have the complex structure of permanent batteries. They were also often designed to be broken down into small parts for ‘mule-back’ transport, and the *Mine & Smelter Supply Co. Catalog No. 22* (1912: 162) quoted prices for both ordinary mills and mills that had been ‘sectionalised’ to 350lb parts.

As Figures 46 and 47 show, these batteries had battery posts that were bolted directly to the sides of the mortar box, making them a single operational unit that could be set up to run on a simple foundation. The stamp weights ranged between 250lb and 850lb (Mine & Smelter Supply Co. 1912: 162; Richards 1906: 209).
Figure 46. Portable stamp mills from the Mine and Smelter Supply Company Catalog No 22 of 1912.

Figure 47. Triple-discharge two stamp mill by Joshua Hendy Machine Works, San Francisco (Richards 1906: 209).
Stamp Guides

Between the battery posts were mounted sets of guides that held the stamps in their vertical plane (Figures 48 & 49), and in lighter mills were also often the lateral structural members of the mill frame. In heavy frames this structural role was performed by heavy beams (guide girths or guide timbers), and the stamp guides were attached to these beams. There were two sets of guides for each set of stamps, one above the camshaft and one below. Generally, the guide had to hold the stamp stem, but not impede its movement, and be adjustable for wear. The guides could be solid or sectional, and were constructed of iron or timber. When timber, the guides were made from two pieces of a hard fine-grained wood, each piece grooved to accommodate the stamp stems. Lock (1901: 312) mentioned the use of naturally greasy ‘tallow wood’ in New South Wales, while Richards (1906: 156) listed a wide range of timbers, including pine, maple, oak, yellow birch, pitch pine, as well as generic ‘wood’ and ‘hard wood.’ The guides were bolted face to face across the stamp stems, with wedges between the two halves to maintain a good clearance for the stems to rise and fall (Truscott 1923: 147). Iron guides were commonly used in Australia (Richards 1906: 156), although Del Mar (1912: 35) thought that short iron guides were one of the main causes of stem wear. However, once again illustrating a contemporary divergence of opinions, Lock (1901: 310) considered iron guides, lubricated with graphite and soft soap, to be the best form of guide.

Figure 48. Various types of stamp guide (Gordon 1906).

Figure 49. Various types of stamp guides from Richards (1906).
**Group 2: The Mortar**

The mortar structure had two main components: the mortar foundations (mortar block or mortar baulks), and the mortar box.

**Mortar Block**

As discussed above in Group 1 (The Frame), the stamper battery foundations were in two parts; the structure that supported the stamper frame, and the mortar blocks that supported the mortar box; in order to isolate the vibration between the two structures.

The mortar block was a timber or concrete structure set into the ground, which supported the combined weight of the mortar, falling stamps and ore that was being crushed. It was important that the mortar block was solidly founded, as its had to resist the vibrations of the stamps as well as the weight of the static plant; “the greater the rigidity of a stamp-mill mortar box and its foundations, the greater will be the percentage of the energy of the blow usefully expended in crushing the ore” (Morison & Bremner 1900: 180).

Mortar blocks were originally always constructed from timber, as it was thought that concrete would not withstand the vibration from the stamps, nor the stamps the ‘shivering rebound’ from the concrete (Truscott 1923: 143). However, experience proved otherwise, and by the first decade of the twentieth century concrete had become the preferred material (Caldecott 1909: 65; Del Mar 1912: 79; Gowland 1914: 201; Morison & Bremner 1900: 180; Truscott 1923: 143). Concrete mortar blocks were cheaper to set up, required no repair or renewal, apparently made the blow of the stamp more effective (Truscott 1923: 144), and even gave the mill a neater appearance (Del Mar 1912: 82).

**Timber Mortar Blocks**

Timber mortar blocks generally consisted of heavy vertical timber baulks bolted together and solidly set into a foundation trench (Figures 50 & 51). As an alternative to large section timbers, the baulks could be built up from planks spiked together (Del Mar 1912: 80; Louis 1902: 125). This latter practice allowed easy repair and replacement of defective areas of timber, and was cheaper to build as it was easier to buy and handle planks rather than single large blocks (ILT 1902: 36-37).

The blocks varied in length; Truscott (1923: 143) suggested about 12 feet, Del Mar (1912: 80) gave a range of 8 feet to 15 feet, and Gordon (1906: 375) stated that they ‘vary in length according to circumstances in every instance,’ and this depth could be 4 feet or 20 feet. Their bases were preferably set on a solid foundation, such as a horizontal bed log, concrete or compacted tailings (Del Mar 1912: 81; ILT 1902: 36; Louis 1902: 125). A pad of rubber or tarred material blanket was placed between the top of the mortar block and the iron mortar box (Del Mar 1912: 81; Louis 1902: 126). The mortar box was secured to the baulks by heavy vertical bolts (anchor-bolts), with plates and cotters at their lower end set into a seat cut in the face of the timber. It was important that there was sufficient clearance for the bolts to be removed and replaced in the case of breakage. Sometimes the anchor bolts had rings in their ends through which was passed an iron bar that ran horizontally through the mortar block (ILT 1902: 37).
Figure 50. Front elevation of timber stamp frame sectioned to show mortar block construction detail (Gordon 1894 with annotation).

Figure 51. The North Star stamp mill in Grass Valley California, with 14 feet long timber mortar blocks (Abadie 1895; Richards 1906).
The varieties of timber used for mortar baulks varied depending on the availability of suitable trees. In New Zealand Gordon (1906: 375) mentioned the use of kauri for the mortar blocks, due to the large size of the timbers that were available, while in America Del Mar (1912: 81) suggested spruce or sugar pine as these woods were better in damp conditions than other pines. Louis (1902: 123) considered pitch pine to be one of the best materials, and Australian karri to also be very good. Del Mar (1912: 82) stated that the mortar baulks should be kept dry to prevent decay, and even suggested that a concrete casing around the baulks above the ground line could be used.

**Concrete Mortar Blocks**

Concrete mortar blocks were a different shape to timber blocks, being typically cast with a wide base and narrow top and sloping sides (Figure 52) (Truscott 1923: 144-146). They tended to be very heavy (explaining their greater solidity when compared to timber blocks), although Truscott (1923: 144) stated that the weight could be reduced without affecting their strength by casting a central tunnel through the middle through which a man could crawl.

![Figure 52. Isometric view of a concrete mortar block (Richards 1906).](image)

The holding down bolts for the mortar box could be arranged in various ways. If a central tunnel was used the bolts were so arranged as to end in this tunnel (Truscott 1923: 144). For solid blocks the holding down bolts were either mounted in a similar fashion to those in timber blocks, running down the face in slots to terminate with plates and timber straining blocks, or were set into the block itself (Figures 53 & 54) (Del Mar 1912: 91).
In common with timber baulks, concrete baulks also required a padding material between the concrete and the base of the mortar box. Materials used included rubber, lead sheet, blanket and timber (Del Mar 1912: 89; Louis 1902: 127). This pad was not intended to act as a cushion, but rather to ensure an exact and close joint between the concrete and the cast iron. Sometimes a cast-iron anvil block (Figure 55) was used below the mortar box to increase solidity when stamps that were very heavy in relation to the mortar box weight were used or to protect the concrete foundations from breakage, although some engineers thought that they had little effect and that concrete foundations alone were adequate (Caledcott 1909: 65; Del Mar 1912: 89; Louis 1902: 132; Morison & Bremner 1900: 180; Truscott 1923: 139).
Figure 55. A cast iron anvil block placed between the mortar box and concrete mortar block (Caldecott 1909).

As concrete became more popular, some batteries were rebuilt with concrete blocks replacing their earlier timber foundations, the opportunity also often being taken to install heavier stamps (C.O. Schmitt, contributed remarks p. 97 in Caldecott 1909). Figure 56 shows a South African battery in its original, timber framed, state, and after the mortars and some other framing had been cut away and replaced with concrete.

Figure 56. Cross-section of the stamp battery of the Simmer and Jack Proprietary Mines, Germiston, South Africa (Schmitt in contributed remarks p. 97, Caldecott 1909).
The Mortar Box

The mortar box was a large box in which the operation of stamping took place (Figure 57). It had four functions (Richards 1906: 161-163):

- To receive ore from the feeder.
- To place it under the stamp.
- To give the stamps the freedom to strike their blows.
- To discharge the water and pulverised ore or pulp, and often to amalgamate gold.

Figure 57. Cut-away drawing showing how the stamps, dies and screens fitted in a typical iron mortar box (ILT 1902).

Crushing could be carried out either dry or wet. Dry crushing produced a great deal of dust, which created a serious health hazard for the workers (see Chapter 11). In terms of the processing of ore, each approach had advantages and disadvantages, but over time wet crushing became favoured, and most batteries therefore had provision for water supply to the mortar.

The typical mortar box was made of cast iron. As with the other parts of the stamp mill, the basic form of the mortar was clearly descended from the older precursors of the Californian stamper battery, but details of its design and materials were constantly modified and refined to suit local conditions:

Each style has an advocate, because that style may be particularly adapted to the work in hand; but the best mortars are built to meet the circumstances of high and low speed, inside and outside amalgamation, high and low drop, also convenience, and all these particulars cannot be embodied in one mortar. (ILT 1902: 30)

The main elements of the box subject to variation were the internal and external dimensions, the weight, the ore feed, the placement of plates for inside amalgamation, the use of internal liners, the number of screens (front and/or side/rear discharge), screen inclination and screen size. As such, there was a wide variation in the design of mortar boxes around a common general form. Some of these designs were named for the mill where they were used, such as the Homestake (a high, narrow box designed for rapid crushing) (Figure 58), while others simply fell into broad design categories. Many small variations, rather than being an example of design evolution, were simply examples from a range of different manufacturers.
Figure 58. Sections of the Homestake Mortar (Richards 1906).

The earliest designs of mortar boxes used in America were constructed of wood which by 1870 were completely outdated (Raymond 1870: 660; Phillips 1867: 173; (ILT 1902: 43-44; Richards 1906: 164). Wooden mortar boxes were constructed of plank timber, bolted to a timber frame and lined with sheet iron, and fitted with a cast-iron bed at the bottom (Figure 59). They had a number of drawbacks, including leakage, lack of durability and the considerable time involved (Louis 1902: 128; Paul 1895: 526; Raymond 1870: 660). The use of cast-iron one-piece mortar boxes answered these problems, and by 1870 iron boxes had been widely adopted in America (Raymond 1870: 660). The main exception to the use of one-piece iron boxes was the manufacture of ‘section (or sectional) boxes.’

Figure 59. A cross-section of a stamp mill with a timber mortar box (Richards 1906).
Sectional Mortar Boxes

‘Section’ or ‘sectional’ mortar boxes were made of a number of bolted-together cast iron and boiler plate sections (Figure 60), and were designed to be disassembled for transport to remote and mountainous areas (ILT 1902: 33; Raymond 1870: 661; Richards 1906: 164). There were a number of different patterns of sectional box, some of which broke down to smaller parts than others. The bottom was made from a series of cast iron sections that were tongued, grooved and planed to be an exact fit with each other, and were secured with long bolts. The upper section was made from sheet iron or steel, riveted or bolted to the bottom (Louis 1902: 162; Richards 1906: 164). Louis (1902: 162-163) was of the opinion that sectional boxes were always troublesome as they leaked and worked loose due to vibration, and should only be used if absolutely necessary (see also AJHR 1885 C2: 3).

Figure 60. A sectional mortar box (Mine & Smelter Supply Co. 1912).

Mortar Box Shape, Size & Weight

The most common basic form of the cast-iron mortar box was a rectangular box designed to receive a set of five stamps. As already discussed above in *Group 1 The Frame*, larger batteries were simply constructed by adding more mortar boxes, one to each additional five stamps. Although uncommon, six-stamp mortars were produced (Raymond 1870: 660). Smaller mills, with one, two, three or four stamps had smaller mortar boxes to suit. In some cases numerous individual one-stamp mortar boxes were used, one extreme case (albeit in a copper rather than gold mill) being at the Boston Consolidated Copper Co. mill in America that had 312 single Nissen stamps (Caldecott 1909: 62).

The basic dimensions of the mortar box were determined by the number and size of the stamps to be used. The weight of the stamps did not directly affect the mortar box dimensions, as it was the diameter of the stamps and the clearance around them that was important (Truscott 1923: 139), and stamp head diameter was similar for both light and heavy stamps (see discussion below). However, the stamp weight did affect the required mortar box weight, as the box had to be heavy enough to provide a firm footing for the dies under the shock of the falling stamps. The weight in a mortar box was not dependant entirely on its dimensions, but also on the depth of metal in its base. Table 2 gives typical five-stamp mortar box dimensions according to Louis (1902: 131), Richards (1906: 165) and Truscott (1926: 142), and Table 3 gives typical weights of mortars and stamps at the turn of the twentieth century according to Louis (1902: 131).
Table 2. Typical mortar box dimensions. (Louis 1902: 131; Richards 1906: 165; Truscott 1923: 142).

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Louis 1902</th>
<th>Richards 1906</th>
<th>Truscott 1923</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>45 to 60 inches</td>
<td>54 to 60 inches</td>
<td>57 inches</td>
</tr>
<tr>
<td>Width at base</td>
<td>18 to 24 inches</td>
<td>23 to 29½ inches</td>
<td>28 inches</td>
</tr>
<tr>
<td>Height</td>
<td>39 to 56 inches</td>
<td>48 to 60 inches</td>
<td>60 inches</td>
</tr>
</tbody>
</table>

Table 3. Typical mortar box weights in about 1900 (Louis 1902: 131).

<table>
<thead>
<tr>
<th>Stamps per mortar</th>
<th>Weight of stamp (lbs)</th>
<th>Weight of mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1250</td>
<td>4 tons</td>
</tr>
<tr>
<td>5</td>
<td>1050</td>
<td>3 tons 5 cwt</td>
</tr>
<tr>
<td>5</td>
<td>950</td>
<td>2 tons 17 cwt</td>
</tr>
<tr>
<td>5</td>
<td>900</td>
<td>2 tons 10 cwt</td>
</tr>
<tr>
<td>5</td>
<td>850</td>
<td>2 tons 5 cwt</td>
</tr>
<tr>
<td>5</td>
<td>750</td>
<td>2 tons</td>
</tr>
<tr>
<td>5</td>
<td>700</td>
<td>1 ton 16 cwt</td>
</tr>
<tr>
<td>5</td>
<td>650</td>
<td>1 ton 13 cwt</td>
</tr>
<tr>
<td>5</td>
<td>550</td>
<td>1 ton 10 cwt</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>1 ton 8 cwt</td>
</tr>
<tr>
<td>5</td>
<td>400</td>
<td>1 ton 2 cwt</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>8.5 cwt</td>
</tr>
</tbody>
</table>

Ore Feed into the Mortar Box

Ore was fed into the mortar box either by hand or by an automatic ore feeder through the feed shoot at the rear of the mortar box (Figure 61). This shoot was positioned so that the ore was delivered to the middle of the dies when they were in their proper position (ie properly placed in the mortar box and unworn). The widest shoots stretched from the centre to centre of the two end stamps (Louis 1902: 132), while narrower shoots extended across the middle half of the box, and dropped ore onto the middle stamps. The splash created by the drop of the stamps then redistributed the ore to the ends of the box (Truscott 1923: 142). The size of the ore feed opening controlled the maximum size of broken ore that could be fed into the battery; Louis (1902: 132) recommended 2 ½ to 3 inches in the clear, and a little less at the top, and Truscott (1923: 142) suggested 3 ½ inches. Some ore feeds had internal return lips to prevent any lumps of ore being thrown back out of the feed by the action of the stamps.

Figure 61. Mortar box section, showing the locations of the ore feed at the rear and the screen at the front (adapted from ILT 1902).
**Mortar Box Internal Design**

Once ore was inside the mortar box the output was controlled by the interplay of a number of different design variables. Amongst these, the depth of discharge and the clearance around the stamps were key considerations.

The depth of discharge (also referred to as the height of discharge or the depth of issue, see Figure 62) was one of the most important working adjustments in a stamper battery (Richards 1906: 165; Truscott 1923: 142). This was the height of the lower edge of the screen above the top level of the dies (Del Mar 1912: 10, 12), and was thus the minimum depth of pulp that was held within the mortar box. The depth of discharge generally varied between 2 to 15 inches (Truscott 1923: 142). As the dies wore this depth would change, which required the die height (using false bottoms, discussed below) or the screen height (using chuck blocks, also discussed below) to be adjusted. Generally a shallow discharge gave a quick coarse & granular output, while a deep discharge gave a slower finer output. Much of this difference was due to the time that the pulp spent inside the mortar box. If the pulp was held within the mortar box for too long it would be crushed too fine (or ‘overstamped’), and would have a high proportion of slimes (Caldecott 1909: 67; Truscott 1923: 142-143). Conversely, if the pulp was discharged quickly, it was likely to be very granular and coarse (Louis 1902: 157; Richards 1906: 165; Truscott 1923: 143). Whether or not inside amalgamation (the use of mercury inside the mortar box, discussed in detail below) was used was an important consideration; if it was used then the depth of discharge should have been over 5 inches, whereas if not then the discharge needed to be kept low (although not less than 2 inches (Del Mar 1912: 29).

![Cross-section of a mortar box](image)

**Figure 62. Cross-section of a mortar box (adapted from Richards 1906) with annotations showing the Depth of Discharge.**

The minimum clearance around the stamps should have been larger than the maximum size of the ore fed in, to prevent the stamp becoming wedged against the side of the box (Richards 1906: 165-166), but once this had been taken into account, a narrow mortar box tended to crush ore quickly and a wider box more slowly (Del Mar 1912: 22; Richards 1906: 165; Truscott 1923: 142). The distance from the stamp to the screen, whether inside amalgamation was used, and whether internal wear linings were fitted were also critical considerations when determining inside dimensions. If the screen was too close to the stamp it would be abraded by the splash and wear rapidly, but if it was too far away from the stamps only the finest
particles would reach it, which influenced the rate and particle size of discharge (Truscott 1923: 142). Inside amalgamation plates would also be abraded if they were too close to the stamps (discussed further below), while inside linings needed to leave adequate clearance around the stamps.

**Inside Amalgamation**

Inside amalgamation was where mercury was used within the mortar box to trap gold prior to the discharge of the pulp through the screens and over the tables. This was done in two ways; by mounting a copper amalgamating plate (or plates) within the box (Figure 63), and/or by the addition of free mercury into the box. The amalgamation plate was usually mounted at the front of the box, below the screen, but rear plates were sometimes also used. Mercury was fed in with the ore at intervals both when amalgamating plates and when free amalgamation was used (Gowland & Bannister 1930: 259; Liddell 1945: 303; Phillips 1867: 178; Rickard 1898: 158). Gordon (1894: 317) stated that although common in America, the use of internal plates in the Australasian colonies was rare, while Ulrich (1875: 66) stated that in Otago it was the ‘regular custom’ to put mercury in the mortar boxes.

![Figure 63. A cross-section of a mortar designed for inside amalgamation, with copper plates mounted both back and front (adapted from ILT 1902).](image)

One implication of the use of inside amalgamation plates in a mortar box was that more space was needed to control the effects of the splash. If the copper plates were too close to the stamps the scour from the pulp would strip the amalgam from the plates and wear the plates themselves away (Del Mar 1912: 22). To prevent this, if a front plate was to be used the mortar box would be made 2 to 3 inches wider at the surface of the discharge, and if a rear plate was to be used the mortar would be wider again with a recess cast in below the ore shoot to protect the plate from the falling ore. Del Mar (1912: 22) stated that standard amalgamating mortars were from 17 to 18 inches wide at a 6 inch discharge. Effectively, a narrow mortar box width characterised a box used solely for crushing, while a wide box was typically have been used for crushing and amalgamation (Truscott 1923: 142). The effect of these modifications to the box shape was to slightly reduce its crushing power, but generally to improve its gold saving ability. Louis (1902: 154) stated “what the battery loses in efficiency as a crushing, it gains as an amalgamating machine.”
The amalgamating plates themselves could be mounted in several ways; directly to the mortar box casting using screws in wooden plugs, or the front plate could be mounted to the timber chock (or chuck) block at the base of the screen. This latter method had the advantage that the plate could be raised or lowered with the screen when depth of discharge was adjusted as the dies wore. Plates mounted directly on the mortar box casting were not adjustable, and so were not ideally placed for much of the wear cycle of the battery (Louis 1902: 154).

Over time there was a decrease in the use of inside amalgamation and an increased focus on outside amalgamation, cyanidation and chlorination (Morison & Bremner 1900: 157). In the early twentieth century as coarser crushing was adopted and tube mills were used to carry out the finer secondary crushing, inside amalgamation was abandoned (Liddel 1945: 304). These changes were at least in part due to the increased treatment of low grade ores, which required a rapid crushing and treatment rate (Morison & Bremner 1900: 157).

**Inside Linings**

Mortar boxes were susceptible to wear in the feed shoot and at the sides of the box that were hit by the splash of pulp from the stamps. These areas were often fitted with iron or steel liners (Figure 64) that were from ½ to 1 inch thick (ILT 1902: 33; Louis 1902: 132, 158; Richards 1906: 166). These were bolted in place, and could be replaced when worn out. The time that the liners would last was entirely dependent on the nature of the ore and the work that the mill did, but Richards (1906: 166) gave American examples where the liners lasted from 6 to 12 months. Liners were sometimes retro-fitted to already-worn mortar boxes to lengthen their lives (Richards 1906: 166).

![Figure 64. Mortar box fitted with liner-plates under the ore feed and along the ends and sides (adapted from Truscott 1923).](image)

**Outlets: Single & Multiple Discharge, Screens**

One of the most critical considerations of the mortar box was the way it discharged. The role of the depth of discharge has already been discussed above, but there were a number of other design features that were also important, namely the number and location of the outlets, the inclination of the screens, the method of screen attachment and the screen material. The screen was a piece of wire mesh or perforated metal sheet that allowed crushed ore to pass through, and was mounted over the outlet opening (or openings) of the mortar box (Figure 65).
Figure 65. The location and mounting of a single inclined front screen (adapted from ILT 1902).

Single Discharge Boxes

The most common pattern was for the mortar box to discharge through the front, which was termed a ‘single-issue’ or ‘single discharge’ mortar (see Figure 65 above). The screen would discharge straight onto the tables or pulp launders in front of the mill.

Multiple Discharge Boxes

Multiple issue (or discharge) mortar boxes used openings and screens in the sides and/or rear as well as the front screen (ILT 1902: 30; Louis 1902: 149; Richards 1906: 167). Double discharge mortar boxes used front and rear screens (eg Louis 1902: 30), while triple discharge mortars used front and side screens (eg Richards 1906: 210). When a rear screen was used, the ore feed had to be raised (see Figure 66). There could be some variation in terminology, and Rickard (1898: 156) illustrated what he described as a double-discharge mortar box from Victoria, Australia that had front and side screens, and so could also be considered to be triple-discharge (Figure 67 below).

The main reasons for the use of multiple outlets was to increase the discharge area, and therefore increase the crushing capacity, or to minimise the sliming of the ore (Richards 1906: 167). They were often used when dry crushing was carried out (ILT 1902: 30; Richards 1906: 167).
The obvious expected advantage of multiple outlets would be to increase the rate of discharge (Ulrich 1875: 66), but contemporary authors were mixed in their opinions. The general tenor of comments is that they did not perform as well as would be expected: “over and over again men have built double discharge mortars; and after trial have blocked up one side, and returned to single discharge” (W. McDermott in discussion p. 84, Caldecott 1909). Louis (1902: 149-150) was very dismissive of them, and stated that in practice it was found that rear screens wore more quickly, failed more regularly, were harder to replace and received less maintenance than front screens. With ore feed from the rear, ore generally fell on the rear two thirds of the dies, meaning that large lumps were thrown backwards into the screen, and in addition the need to raise the ore feed meant that ore fell against the stamps themselves and
could also be thrown back into the rear screen. When added to the difficulty of access for maintenance or replacement because the rear screen was often below the feed platform, he concluded that there was no benefit in using double discharge boxes. Caldecott (1909: 58-59) reported similar findings from an extensive series of trials in South Africa in 1904, where double discharge mortars produced no greater stamp duty than single discharge mortars, but used considerably more water. In New Zealand, Ulrich (1875: 66) was of the opinion that double-discharge mortars would be more effective than single-discharge, but did not discuss any examples to support this.

In cases where multiple-discharge mortar boxes were found to be unsuccessful, the rear openings were sometimes covered with sheet iron, effectively converting the boxes to single-discharge (Louis 1902: 149).

**Screen Mountings**

There were two main patterns of screen mounting; the bolt or clamp on screen, and the slot-mounted screen. The outlets in mortar boxes with bold-on screen were generally divided into two, with a central cast vertical strengthening rib, and the two small screens were mounted either side of the rib. They were fastened by a variety of methods, including studs, bolts and nuts, cotter bolts or straps secured by wing nuts, although Louis (1902: 133) cautioned that any screw threads near the face of the screens were likely to be scoured by the passing pulp. Louis (1902: 134) was also of the opinion that the use of divided screens was undesirable as it reduced the available discharge area.

The slot mounted screens were usually constructed with wooden frames that slid down into slots in the mortar box, and were held in place by steel keys (see Figure 65 above). Iron frames were sometimes used, but Louis (1902: 133) advised against these because of the weight and the difficulty in getting a good seal. The height of the bottom of the screen above the level of the dies (the depth of issue or discharge) could be adjusted by inserting wooden chuck-blocks of various sizes beneath the screen.

The angle of the screen mounting also varied (Figure 68), and screens were either vertical or inclined out at the top (Richards 1906: 176). Louis (1902: 135) stated that the American and usual English practice was to use mortar boxes with inclined screens, while in Australia the practice was to use vertical screens. Inclined screens were certainly in use from an early date, as Phillips (1867: 176) discussed their merits in 1867. The inclined screens sloped out at between 9° and 20°, with about 10° being most common (see also Del Mar 1912: 20; Richards 1906: 176; Truscott 1923: 142). The inclined screen increased the screen surface area available, allowed the quartz particles to travel down the screen more slowly than would be the case with a vertical screen thus improving their chances of passing through, and also increased the distance slightly between the top of the screen and the stamp, improving the life of the screen.
Some mortar boxes had a removable section in the front that allowed access to the base of one of the dies so that it could be prised out when the mortar box was cleaned up (Louis 1902: 160). This opening was below the screen opening, and extended no lower than the apron so that any leakage would still be caught and pass over the table.

**Screens**

After taking into account all of the above details about mortar box design, final discharge was controlled by the screens. The size and density of the holes in the screen determined the maximum particle size and amount that could be passed, but only a small percentage of the pulp passed through was of the maximum screen size, all the rest being much smaller with some reduced to slimes (Louis 1902: 146). While the mortar box design and die heights provided the coarse parameters, the finer setting and on-going adjustment of the depth of discharge was determined by the screen location.

Screen material, size and location were therefore inter-related factors. It was important that the size of the screen material was matched to the depth of discharge, but as was often the case in contemporary sources, there was not always agreement over the details. Louis (1902: 157) thought that a coarse screen should be used for shallow discharge, and a fine screen for deep discharge, but Caldecott (1909: 67, 69) cautioned that using deep discharge and a fine screen was an inefficient use of power, as the most effective crushing was done on coarse lumps of ore, and fine material held in the mortar box cushioned the blow of the stamp. Louis considered that because only a only a small percentage of the crushed ore that passed through the screen was of the maximum size, a coarser screen than expected could be used, with the small proportion of coarse pulp easily separated off and returned to the mortar box. He commented that in general mill men were in the habit of crushing through too fine a screen (Louis 1902: 148).

In the early twentieth century tube mills became common as a second stage of processing after the stamps, and coarse screens replaced finer mesh in stamp mills so equipped. The stamps then carried out coarser crushing, and the stamp duty could be increased. (Caldecott 1909: 70, author’s reply, p. 138-139).
**Screen Material**

Screens were of two main types: perforated (punched or drilled) metal sheets, and woven wire (steel or brass) sheets (Del Mar 1912: 14-15; ILT 1902: 34; Richards 1906: 167). The size of the holes in the screens and the relative area of holes to the overall area of screen (ie, the hole spacing) were the critical factors, as the two together controlled the amount of material that could be passed through (the aperture size and measurement systems for screens are discussed below).

Perforated metal sheets came in a variety of materials and forms, and mild steel sheet, charcoal iron sheet, Russian sheet iron, and tinplate with the tin burnt off were all widely used (Gordon 1894: 312; 1906: 385-386). Sheet copper could be used, but not where internal amalgamation was employed in the mortar box as the mercury amalgam would stick to the screens and choke them (Louis 1902: 140). Aluminium bronze screens (95% copper and 5% aluminium) avoided this problem, were found to wear very well, and could be melted down to be recycled when worn out, but were very expensive (Gordon 1906: 386; ILT 1902: 34; Louis 1902:140).

Sheet metal screens could be perforated with round holes or slots (Figure 69) that were either clean or burred. Patterns included horizontal, vertical or angled rows of slots in parallel or break-joint lines, or round holes in 90° or 60° rows. Different patterns had different advantages and disadvantages; for example parallel rows of slots created a weakness along which a screen could split (Louis 1902: 137), and round holes in 60° degree rows allowed a slightly higher percentage of opening than 90° holes for the same hole diameter and spacing (Richards 1906: 168; Truscott 1923: 220).

![Figure 69. Perforated metal sheet screens (ILT 1902; Richards 1906).](image)

Wire mesh screens (Figure 70) were generally made from woven steel or brass wire in square or oblong meshes (Del Mar 1912: 15; Louis 1902: 143; Rickard 1898: 52). Crimped wires were often used to ensure that the screen stayed in shape (Richards 1906: 170; Rickard 1898: 53; Truscott 1923: 221).

![Figure 70. Woven wire screens (Truscott 1923: 221).](image)
Wire mesh screens had a higher discharge area than perforated sheet screen, but were less durable (Louis 1902: 143; Richards 1906: 171; Rickard 1898: 54; Truscott 1923: 221). As perforated screens were more expensive, the actual cost per ton of ore crushed tended to work out about the same as for both types (Louis 1902: 143), and the choice of which to use therefore came down to other considerations than simply the cost of the screen. These included the desired rate of discharge, whether a coarse pulp was desired and whether the ore contained coarse gold (Louis 1902: 144). However, in general, several authors simply stated that the choice of screen in any given situation came down to experimentation to find the best material and size to suit the ore at hand (Del Mar 1912: 14, 16; Gordon 1906: 387; ILT 1902: 33; Richards 1906: 174).

**Measurement of Screens**

There were a variety of screen measurement systems, with differences between countries and different systems for perforated sheet and wire mesh, and even between steel wire and brass wire meshes. In England and Australia screens were generally described by the number of holes per linear or square inch, and in America screens were described by trade numbers corresponding to the size of needle that could just pass through the holes (Louis 1902: 138-139). In New Zealand Gordon (1906: 386) used the meshes to the linear inch for mesh screens and the needle-number for perforated screens (Table 4). These needle numbers were the same as those used for sewing machines. He stated that in New Zealand iron or steel wire mesh screens were mostly used varying from No. 20 (for coarse ores) to No. 60 (for ores with very fine gold).

**Table 4. Screen measurements.**

*List of needle numbers, mesh numbers and the corresponding hole sizes from Gordon (1906) & Richards (1906).*

<table>
<thead>
<tr>
<th>No. of Needle</th>
<th>Corresponding Mesh</th>
<th>Width of Slot (inches)</th>
<th>Width of Slot (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>20</td>
<td>0.029</td>
<td>0.74</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>0.027</td>
<td>0.69</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>0.024</td>
<td>0.61</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>0.022</td>
<td>0.56</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>0.020</td>
<td>0.51</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>0.018</td>
<td>0.46</td>
</tr>
<tr>
<td>11</td>
<td>55</td>
<td>0.016</td>
<td>0.42</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>0.015</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**Screen Frames**

The screen material was mounted on frames that were usually made of timber, although some manufacturers used iron. In New Zealand, Gordon (1906: 387) stated that kauri or red pine (rimu) were used for these frames. When wire mesh was used the frame had several vertical ribs to strengthen the screen (Figure 71), while a single rib was used with diagonal-slot screens (ILT 1902: 35; Richards 1906: 176).
Figure 71. A wooden frame for wire mesh screen (adapted from Rickard 1898).

Screens were the part of the stamper mill that wore most rapidly, and therefore required regular replacement. As the greatest wear on screens was at the base, and this is where they always gave way first, it was often recommended that the frames be made the same top and bottom, so that a partially worn screen could be turned upside down to increase its life (Del Mar 1912: 20; Louis 1902: 134). Louis (1902: 134) also recommended that a duplicate set of screens should be kept ready to be used at a battery so that in the case of screen failure a new set could be quickly put in place.

Mortar Box Covers

The top of the mortar box was generally covered by boards or iron sheet to prevent grease from the cams falling into the pulp. These covers were generally made from two boards, each with a row of half-hole along one edge to fit against the stamp stems (Richards 1906: 167). Any grease present would prevent gold from amalgamating with mercury (Liddel 1945: 303).

Screen Cover/Splashboard

Screen covers were mounted in front of the screens to ensure that the pulp that passed through the screen fell directly on to the head of the tables (Gordon 1906: 387; Richards 1906: 177). These covers could be wooden or canvas, as their job was simply to catch the splatter from the screens.

Water Supply

When wet crushing was employed a constant supply of water to the mortar box was necessary, which could be fed in at the top, front or rear. Del Mar (1912: 24) stated that the California mill of 850 to 1050lb used from 5 to 7 US gallons (4 to 5.8 imperial gallons) of water per stamp per minute for all purposes other than power, although where water was scarce 1 US gallon (0.8 imperial gallon) per stamp per minute would suffice, depending on the nature of the ore.
Group 3: The Lifting Mechanism

The lifting mechanism consisted of the camshaft and cams that lifted and dropped the stamps, together with any associated bearings and fittings.

Figure 72. A camshaft with drive pulley and five cams mounted (Clark 1904).

Camshaft

The camshaft was the wrought iron or steel shaft upon which the cams were mounted (Figure 72). In 1912 Del Mar (1912: 72) commented that while it had been the practice earlier to use a single long camshaft for 20 stamp batteries, the current practice was to have a separate shaft for each ten stamps, although the best arrangement would be five stamps to a camshaft to reduce vibration. The advantage of using shorter camshafts was that each battery could be stopped independently of the others for repairs or adjustment, while the disadvantages included the expense of a double number of drivers, the need for more room, and more wearing parts (Louis 1894: 165).

The diameter of the shaft depended largely on the work that it had to do, specifically the weight of the stamps that it needed to raise. Wiard (1915: 337) and Richards (1906: 191) published tables of camshaft diameters related to stamp weights, ranging from a 4 3/8 inch shaft for 750 lb stamps to a 7 inch shaft for 1800 lb stamps. Their figures are summarised in Table 5. Wiard’s figures are a set of recommended sizes, while Richard’s are examples from contemporary mills, but it can be seen that both sets show a general increase on size of shaft for increasing stamp weights.

The camshaft could be mounted on the battery frame either in front of or behind the stamp stems (Richards 1906: 155). Figures 40 and 41 above (in Group 1 The Frame) illustrate back and front mounted cams. The camshaft bearings were securely mounted on the battery posts, and could either be covered or open (Figure 73). It was important to ensure that oil and grease did not fall into the mortar box, as it would ‘sicken’ the mercury used for amalgamation, and bearings were sometimes equipped with oil grooves and drip pans to catch any leaking oil (Figure 73) (Richards 1906: 190-191).
Table 5. Camshaft diameters for various stamp weights from Wiard (1915) and Richards (1906).

<table>
<thead>
<tr>
<th>Stamp weight (lbs)</th>
<th>Shaft dia. (inches) (Wiard 1915)</th>
<th>Shaft dia. (inches) (Richards 1906)</th>
</tr>
</thead>
<tbody>
<tr>
<td>650</td>
<td>4 3/8, 5</td>
<td>6</td>
</tr>
<tr>
<td>750</td>
<td>5 ½, 6</td>
<td>5 ½</td>
</tr>
<tr>
<td>800</td>
<td>5, 5 ¼</td>
<td>5, 5 ½</td>
</tr>
<tr>
<td>850</td>
<td>5 3/8</td>
<td>5, 5.4, 4 ½ to 5 ½</td>
</tr>
<tr>
<td>900</td>
<td>5 3/8</td>
<td>5 ½</td>
</tr>
<tr>
<td>930</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>950</td>
<td>5 ½</td>
<td>5 3/8</td>
</tr>
<tr>
<td>1000</td>
<td>5 ¼</td>
<td>5 ½</td>
</tr>
<tr>
<td>1050</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td></td>
<td>5 7/8</td>
</tr>
<tr>
<td>1150</td>
<td>6 ½</td>
<td></td>
</tr>
<tr>
<td>1250</td>
<td>6 15/16</td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>6 15/16</td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td>6 15/16</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>6 15/16</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Figure 73. Cam shaft bearings (Mine & Smelter Supply Co. 1912; Richards 1906).

Cams

The cams used in the Californian Stampers had two arms set at 180° to each other (Figure 74), and therefore the cam would lift and drop a stamp twice for each revolution of the camshaft.

Figure 74. Side and end elevations of a cam with stiffening webs (ILT 1902).

Each cam arm had a curved face that, as the cam rotated, was brought up against the lower face of the tappet on the stamp stem and lifted it to the desired height before releasing it. An important aspect of the design of the Californian Stamp was that the cam not only raised the tappet, but also revolved the stamp
stem a small amount at each lift, to even out the wear on the shoes and dies.

There were a number of critical design features that determined how cams performed in the field. The mounting of the cam to the camshaft had to be secure, and yet reasonably easy to dismount for repairs. The lift of the cam had to be sufficient to raise the stamp stem the desired height, the rate of lift had to be appropriate to ensure smooth operation, the rotation of the stamp stem had to be sufficient, and issues such as side-thrust had to be addressed. In addition, the cam had to be strong enough to have a long service life without breakage or rapid wear.

**Cam Design & Drop Heights**

The maximum lift and rate of lift of a cam were determined by the curve and length of the arms, while the weight that it could lift was determined by the strength and material of its construction. The curve was the most critical element in the design of the cam, as it determined how the stamp stem was lifted:

“The object of the cam is to convert the uniform rotary motion of the camshaft into an upward motion of the stamp stem, such that the rate of lifting shall be uniform, the action being intermittent, so that time is given it to admit of its falling freely with uniformly accelerated velocity under the action of gravity” (Louis 1902: 202).

The basic shape of the lifting surface was the involute of a circle (Figure 75), with the radius equal to the distance from the centre of the cam shaft to the centre of the stamp stem, which included a small clearance between the two shafts to prevent them touching (Figure 76) (Del Mar 1912: 102; Louis 1902: 202-203; Morison & Bremner 1900: 159; Richards 1906: 196). There are several ways of generating an involute curve, but the easiest to visualise is to have a piece of string wrapped around a circular core (the inscribing circle), with a pencil tied at the end of the string. The curve inscribed as the string is unwound is the involute curve of that inscribing circle.

The involute curve has a number of properties essential to the form of the cam. Firstly, a tangent to the curve will always be horizontal, when the line of lift of the stamp stem is vertical (Figure 76). This meant that the cam bore squarely under the lower face of the tappet as it rose (Louis 1902: 204). The involute curve also provided a constant lift (see Figure 77 below), an important consideration in powered machinery where a constant load is desirable. The final part of the lifting surface often did not follow the involute curve, but was slightly flattened off to produce a diminishing lift for the last part of the lift period. The end of the cam was cut at an angle so that the tappet on falling would leave the cam from an arc of contact of between 1 and 2 inches in length instead of a single point, to prevent the cam cutting and breaking the tappet (Richards 1906: 197).
The maximum height of lift of a cam was determined when laying out the cam curve, but this lift was constrained by several factors. An obvious design feature was that the curve of one arm had to finish prior to the start of the curve of the second arm, because sufficient time had to be allowed for the stamp to fall completely before it was picked up again, allowing for a short rebound period between the drop and lift (Figure 77). This means that there was a maximum possible lift for any given radius of inscribing circle (Louis 1902: 207).

The rate of fall of the stamp was obviously determined by the force of gravity, and therefore a constant, and so the speed at which the camshaft was driven was another key factor. According to Morison & Bremner (1900: 160) the normal interval of rest for a stamp was about 0.1 second after reaching the ore, it being essential that the falling stamp exert all of its energy in crushing the ore before being picked up again. If the camshaft was run too fast and the falling tappet struck the rising cam it was known as ‘camming’ and not only did it reduce the crushing efficiency of the mill, it also would result in breakages of cam and cam shafts (Morison & Bremner 1900: 160-161). It can therefore be seen that there was a fixed relationship between maximum drop height and drop rate (ie drops per stamp per minute). Table 6 gives some examples of this relationship from Truscott (1923) that were obtained by experience. As this table shows, typical drop heights were between 6 ½ and 9 ½ inches. In practice some running adjustment of drop height was also possible by moving the tappet up and down on the stem.
Table 6. Stamp drops per minute and maximum height of drop (Truscott 1923: 154).

<table>
<thead>
<tr>
<th>No. of Drops per Minute</th>
<th>Height of Drop</th>
<th>Total Lift per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>6 ½ inches</td>
<td>715 inches</td>
</tr>
<tr>
<td>100</td>
<td>8 inches</td>
<td>800 inches</td>
</tr>
<tr>
<td>90</td>
<td>9 ½ inches</td>
<td>855 inches</td>
</tr>
</tbody>
</table>

The actual dimensions of cams varied depending on a number of factors, of which the maximum required drop height was the most important for the overall cam diameter (tip-to-tip), but general strength was also an important consideration. The Mine & Smelter Supply Co. (1912: 164) listed cam diameters (tip-to-tip) for different weights of stamp and height of drop (Table 7). This table shows that the greatest variation in overall cam diameter was due to drop height (6 inches variation down the table) rather than stamp weight (2 inches variation across the table). Wiard (1915: 336), listed dimensions for steel cams made by the Chrome Steel Company, and for all stamp weights of 850lb to 1800lb, the cams were 32 inches tip-to-tip, although their other dimensions became more robust as stamp weight increased.

Table 7. Cam diameters, tip to tip, for different weights of stamp and height of drop (Mine & Smelter Supply Co. 1912)

<table>
<thead>
<tr>
<th>Total Weight of Stamp, Pounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>850 to 900.</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

Lateral thrust was another operational issue. Cams were subject to sideways thrust because they did not lift the tappet under the centre of gravity of the stamp, but rather to one side. The cam and the stamp stem were pushed apart horizontally (Figure 78), the degree of lateral thrust being greatest just as the cam left the tappet (Louis 1902: 212; Richards 1906: 195). As tappets wore their face could become conical, which could increase the lateral thrust on the cam (Louis 1902: 173). The effect was that the whole camshaft was pushed sideways away from the stamp stems, and a number of ways of countering this thrust were employed. One method was to use collars running against the camshaft bearings, or the drive pulley could be mounted on the end of the camshaft away from the cam hubs, so that its hub would run against the camshaft bearing and resist movement (Louis 1902: 201). A more elegant solution was to produce cams for mounting either right or left of the stamp stem (Figure 78).
Figure 78. The effect of lateral thrust (left) and right and left handed cams (Richards 1906).

A right hand cam was one mounted to the right of the stamp stem when the top of the cam was moving away from the observer (Louis 1902: 195; Richards 1906: 195; Truscott 1923: 149). A mixture of right-and and left-hand cams would cancel the lateral thrust of each other out. On larger batteries each set of five stamps could be fitted with cams of one hand, the next set having cams of the other hand (Figure 79). On 5 stamp mills a mixture of left and right handed cams could be used, although it was more usual to employ collars or the drive wheel mounting (Del Mar 1912: 22; Louis 1902: 201).

Figure 79. A ten stamp camshaft with both left and right hand cams (Gordon 1894).

The strength and wearing qualities of cams depended on their design and material of manufacture. Cams could be produced from cast iron or cast steel, the latter being stronger and the preferred material (Louis 1902: 195; Richards 1906: 192). If cast iron was used, the dimensions of the hub and strengthening webs were greater than for a steel cam of the same lift, and an iron hoop was sometimes shrunk onto the hub to reinforce it.
Cam Mounting

There were two main methods of mounting of the cam to the camshaft. The earliest and most common technique was to use a keyway cut into both the cam and camshaft (Figures 80 & 81), with a tapered key driven into the aligned keyways to lock the two together. This key was always driven in towards the position of the relevant stamp stem, to resist lateral thrust. Louis (1902: 198) recommended that two keys be used in each cam, particularly for stamps over 700lb in weight. The rotational position of a cam was determined by the location of its keyway, and as such new cams were supplied with no keyway, this being cut as required. This method was simple and strong, but had drawbacks. In particular, if the cam broke and needed replacement it was time consuming to lift the camshaft and drive off the other cams until the broken one could be removed, cut a new keyway in the replacement cam and reassemble the parts. In very well equipped mills the new slot could be cut by a slotting machine, but in most mills it would have to be done by hand using hammer and chisel (Louis 1894:186). Del Mar (1912: 29) commented that with keyed cams they were either so tight that it was a day’s job to get one off, or they were not keyed firmly enough to last.

In 1893 Edward Blanton patented a new method of mounting cams, which rapidly gained popularity due to its effectiveness (Blanton 1902; Clark 1904: 78; ILT 1902: 21; Louis 1902: 198; Richards 1906: 193; Truscott 1923: 152). The Blanton cam was secured by a curved metal wedge that enveloped an arc of about 180°, and was pinned to the camshaft at its thick end, with the thin end pointing in the direction of rotation (Figure 82). The bore of the cam had a corresponding face machined into it, and when mounted on the camshaft with the wedge in place the rotation of the camshaft tightened the cam against the wedge. To dismount the cam it simply had to be knocked backwards, breaking the grip of the wedge. The advantages of this system were that the cams were quick and easy to mount and dismount, and because the rotational position of the cam was determined by the position of the locating holes in the camshaft, spare cams were all the same and did not need individual fitting (Blanton 1902; Richards 1906: 194; Truscott 1923: 153).
The time-saving involved could be considerable; Richards (1906: 194) referred to the experience of a battery in Marysville, Montana, where the strip-down and refurbishment of a ten cam camshaft took less than half an hour, whereas the same job with keyed cams would take a day. Louis (1902: 198) described the Blanton cam as “one of the leading recent improvements of the stamp-mill.” Variations soon became available, including the ‘Canda self locking cam’ (Figure 83) (Mine & Smelter Supply Co. 1912; 165) and the ‘New Blanton Cam’ (ILT 1902: 22; Louis 1902: 198; Richards 1906: 194) all of which acted in much the same way.

Some two-piece cams that could be easily removed from a camshaft were produced, but it was found that the problems with these cams working loose far outweighed any advantage from ease of their removal and replacement (Louis 1902:197; Richards 1906: 192).
Drop Order

The drop order was the order in which each set of stamps within one mortar box was dropped, and was therefore set by the order in which the cams were mounted on the camshaft. There was some variation in the way they were numbered; right to left or left to right; according to Del Mar (1912: 21) and Louis (1902: 209) the usual way was to count from the driving pulley end (which would obviously differ between batteries). Other authorities such as Truscott (1923: 152) and the ILT (1902: 35) simply counted from left to right when looking at the front of a battery (Figure 84), which is the method used in this discussion.

Figure 84. The numbering of stamps (adapted from Clark 1904, advertisement for W. Anderson & Sons).

The stamp drop order was intended to maintain a wash within the mortar box that kept ore and pulp moving under the falling stamps and out of the screens, to stop the build-up of ore in any one place, and to avoid rocking the mill structure (Gordon 1906: 381; ILT 1902: 35; Louis 1902: 209). There were a number of general practices that applied to the drop order, including that no two stamps should fall at the same time (Gordon 1894: 313), that neighbouring stamps shall never be allowed to fall in succession, and while any given stamp is falling, its neighbours shall be rising (Louis 1902: 209). Louis stated that these latter two were at times ‘antagonistic’ and that one or the other should be observed.
A variety of stamp drop orders were used. The New Zealand authority, Gordon, stated that 1-4-2-5-3 gave a good uniform splash, and that in America 1-5-2-4-3 was extensively used (Gordon 1898: 313), and Louis (1902: 209) gave the same drop orders. In a later edition Gordon (1906: 382) added 1-5-3-4-2 as another commonly used order. Truscott (1923: 152) stated that 1-4-2-3-5 was used in California, and 1-3-5-2-4 was used in South Africa. Each of these drop orders had a reciprocal order, where the drop pattern was reversed in direction (eg. 1-4-2-3-5 became 1-5-3-2-4), which could be used interchangeably (Gordon 1906: 382; Louis 1902: 209; Truscott 1923: 152). Table 8 gives some of the drop orders from contemporary sources. As this table suggests, the order 1-4-2-5-3 appears to have been the most popular.

Table 8. Stamp drop orders, their reciprocals, the places where these orders are known to have been used, and the sources quoted.

<table>
<thead>
<tr>
<th>Drop order</th>
<th>Reciprocal</th>
<th>Places used</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4-2-5-3</td>
<td>1-3-5-2-4</td>
<td>NZ, South Africa, US</td>
<td>Louis 1902; Gordon 1906; Truscott 1923; ILT 1902; Mine &amp; Smelter Co. 1912</td>
</tr>
<tr>
<td>1-5-2-4-3</td>
<td>1-3-4-2-5</td>
<td>US</td>
<td>Louis 1902; Gordon 1906; Truscott 1923</td>
</tr>
<tr>
<td>1-4-2-3-5</td>
<td>1-5-3-2-4</td>
<td>US</td>
<td>Truscott 1923</td>
</tr>
<tr>
<td>1-5-3-4-2</td>
<td>1-2-4-3-5</td>
<td></td>
<td>Louis 1902</td>
</tr>
<tr>
<td>1-3-2-4-5</td>
<td>1-5-4-2-3</td>
<td></td>
<td>Louis 1902</td>
</tr>
</tbody>
</table>

For ten stamp batteries the orders of the two sets of five stamps were run together (Gordon 1906: 382), the 1-5-2-4-3 pattern becoming 1-6-5-10-2-7-4-9-3-8 (which had the two sets of stamps running the same order, with No. 6 dropping straight after No. 1. A slightly different arrangement was where 1-4-2-5-3 was extended to 1-8-4-10-2-7-5-9-3-6, which had the second set of stamps running the same pattern but in reverse.

Note that this drop order has neighbouring stamps falling in succession, and as such it meets one of Louis’ two principles, but is ‘antagonistic’ to the other.

It was found that when the drop orders and their reciprocals were examined, several typos were in these references. These orders have been omitted from this discussion.
Group 3: The Stamps

The stamps were the vertical shafts that were raised and dropped by the cams, and which did the actual work of crushing the ore. A stamp consisted of four main parts: the stem, tappet, head and shoe (Figure 85) (Louis 1902: 168).

Figure 85. A cross-section through a stamp mill (adapted from Rickard 1898).

Stamp weight was one of the variables often referred to when discussing any particular mill; for example, a report might refer to a mill of 30 stamps, each weighing 800 pounds. This weight reduced as the shoes wore, and some commentators suggested that average or running weights should be quoted (eg see C.O. Schmitt, contributed remarks p. 97, in Caldecott 1909). However, in general the quoted weights in contemporary literature were for stamps with new shoes.

There was a general trend over time of increasing stamp weight (Gowland 1914: 201; Wiard 1915: 334). The first stamp mill erected in the United States at Tellurium in Virginia in 1835 had 50lb stamps (Caldecott 1909: 57), and in 1867 Phillips stated that stamps ranged from 550 to 900lbs (Phillips 1867: 173). In 1900 Morison & Bremner (1900: 163) were of the opinion that 1000 to 1200lb stamps were almost at the practical limit, and by 1923 Truscott stated that a 1000lb stamp was about the average for contemporary practice, and that 2000lb was the extreme weight possible when using cam-and-tappet lifting (Truscott 1923: 137). These upper weight limits were employed in South African batteries, where at the turn of the twentieth century 1250lb stamps were in common use, rising to 2000lb a decade later (Caldecott 1909: 58; Del Mar 1912: 11, 12; Gowland 1914: 202).

This general increase in weight was because the crushing power of a battery was determined largely by the weight, drop height and drop rate of the stamps. Any increase in the drop height would require a decrease in drop rate (or ‘camming’ would occur, see discussion above), and it was found to be more effective to simply increase the weight (Del Mar 1912: 10). For goldfields with relatively low grade ores it was necessary to crush high tonnages, and experience in places such as Thames and Victoria showed that larger and heavier machinery was necessary (Latham 1984: 174). Concomitant with the increase in stamp weight was an increase in the weight and robusticity of the other stamper battery components in order to support the stamps.

The recommended relative weights of the various stamp components also varied over time and between authors (Tables 9 and 10). Early (1870s) practice was to have the head comprise about 1/3 of the total stamp weight, and this decreased over the next few decades, but then increased again in the early twentieth century in order to lower the centre of gravity of the assembly (Louis 1902: 169; Raymond 1870: 659; Truscott 1923: 137).
Table 9. Recommended and actual relative weights of stamp components from Louis (1902).

<table>
<thead>
<tr>
<th>Part</th>
<th>Recommended</th>
<th>Practice</th>
<th>900lb stamp</th>
<th>1250lb stamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tappet</td>
<td>14%</td>
<td>11.5-16.5%</td>
<td>125lb</td>
<td>150lb</td>
</tr>
<tr>
<td>Stem</td>
<td>43%</td>
<td>35.5-44%</td>
<td>390lb</td>
<td>550lb</td>
</tr>
<tr>
<td>Head</td>
<td>28%</td>
<td>24-33%</td>
<td>255lb</td>
<td>350lb</td>
</tr>
<tr>
<td>Shoe</td>
<td>15%</td>
<td>15-20%</td>
<td>130lb</td>
<td>200lb</td>
</tr>
</tbody>
</table>

Table 10. Recommended relative weights of stamp components at various dates.

<table>
<thead>
<tr>
<th>Part</th>
<th>Raymond (1870)</th>
<th>Louis (1902)</th>
<th>Caldecott (1909)</th>
<th>Truscott (1923)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tappet</td>
<td>11.3%</td>
<td>14%</td>
<td>15.09%</td>
<td>12%</td>
</tr>
<tr>
<td>Stem</td>
<td>41.1%</td>
<td>43%</td>
<td>43.29%</td>
<td>35%</td>
</tr>
<tr>
<td>Head</td>
<td>32.3%</td>
<td>28%</td>
<td>24.55%</td>
<td>37.5%</td>
</tr>
<tr>
<td>Shoe</td>
<td>15.3%</td>
<td>15%</td>
<td>17.07%</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

The Stem

The stem consisted of the shaft onto which were mounted the tappet and head. It could be made from either wrought iron or low carbon mild steel, and Louis (1902: 176) stated that the latter often gave better service as it was less prone to breakage. The stem needed to be sufficiently stiff to resist any spring in working, which would excessively wear the guides, and strong enough not to break, and a large diameter stem was therefore desirable. In practice Louis (1902: 174-175) found that stamp stems varied from 9 to 16 feet long and from 2¼ to 3¾ inches in diameter, while Richards (1906: 187) recorded stems from 11 to 15 feet in length and from 2 7/8 to 3 7/16 inches in diameter.

There were two basic forms of stem, depending on the type of tappet mount that was used: a straight stem for most tappet types, and a stem with one reduced end and a threaded central section for screw tappets (see discussion below on tappets). The straight stem (Figure 86) was the same diameter for its whole length, and had a slight taper (between 0.4 and 1 inch per foot) turned on one or both ends for mounting the stamp head. Ordinary straight stamp stems could wear where they passed through the guides or where the tappet was mounted, and they were prone to breakage near the head or tappet. Wear could cause problems when mounting tappets, as a tappet would not grip a worn stem properly and shims would have to be used (Del Mar 1912: 34). Breakage was a greater problem, as the broken parts would have to be dismounted. If both ends of a broken stem were tapered and the break was near the head, the stem could be inverted and quickly reused (Del Mar 1912: 30; Louis 1902: 175). New tapers could also be machined or forged on the ends of broken stems, this being repeatable until the stem became too short to use.

Figure 86. A standard straight stamp stem, with a taper at each end (Gordon 1894).
On straight stems the tappets were mounted by a variety of wedge methods, discussed further below, which apart from some wear did not otherwise affect the design of the stem. The threaded stems for screw tappets had a weakness where the diameter was reduced above the threaded section, could not be reversed, and were also expensive, costing twice as much as a plain rolled shaft (Louis 1902: 170; Richards 1906: 189).

**The Tappet**

The tappet served to transmit the lift of the cam to the stamp stem. It consisted of a cast iron or cast steel collar fitted to the stem, with a flat lower face upon which the rising cam pressed. On the Californian Stamper the tappet had to be circular in plan, as the action of the cam caused it and the stamp stem to rotate. The tappet had to be adjustable on a regular basis, to take account of the on-going wear to the shoes and dies as the stamper battery ran, but also had to be securely held to the stem so that it did not work loose from the constant action of the cam. Many tappets were made double-ended, so that they could be reversed when one face became worn. A recess was often machined in the face of the tappet against the stem in order to keep the wear even and avoid the creation of a conical shape, which would increase lateral thrust (Louis 1902: 172-173; Richards 1906: 188).

There were several different designs of tappets used, most being secured either by keys acting against the stem, a gib and keys, or a screw thread. The simplest form was a cast iron collar about 2½ inches wide and 6 inches deep held in place by a vertical key, the back of the key being hollowed to fit closely against the stamp stem. Louis (1902: 169) stated that by the date of writing these were never used other than on light prospecting stamps of up to 300 lbs weight. The example illustrated by Louis (Figure 87) was single-sided (ie could not be reversed when worn).

Figure 87. Simple one-sided collar tappet held in place by a key (Louis 1902).

Screw tappets were screwed onto a threaded stamp stem (discussed above). They could be secured either by a lock nut (Figure 88) or by a vertical key in a slot cut into the threaded section of the stem (Louis 1902: 169; Richards 1906: 189). The screw tappet was capable of fine adjustment, but was prone to work loose and wear with the constant pounding of the tappet (Richards 1906: 189). In 1898 Rickard (1898: 160) commented on the use of screw tappets in Australian practice:

> It was found here as elsewhere that while they may answer admirably when first put in position, as soon as they become the slightest bit loose, which cannot be prevented eventually, the screw gets instantly worn and is soon ruined.

As a consequence of this weakness Louis (1902: 169) stated that this type of tappet was abandoned in American mills by about 1870 (see also Raymond 1870: 658), although its use continued in Australia.
The form of tappet most highly regarded by contemporary authors was the ‘Californian’ or ‘Wheeler’ gib tappet (Figure 89), so named because it was invented by Zenas Wheeler, and which was widely used by 1870 (Louis 1902: 172; Paul 1895: 528; Raymond 1870: 658; Richards 1906: 188). This was a reversible cast tappet that was secured by a wrought iron or forged steel gib and two or three tapered keys. The gib had a concave front surface to fit against the stem, and the keys were driven in across the rear of the gib (ie across the line of the stem and gib). This type of tappet was quick and easy to adjust, and remained tight in use (Richards 1906: 189).

The Stamp Head

The stamp head (or boss) was mounted on the end of the stem, and in turn provided the mounting for the shoe (Figure 90). The head consisted of a cast iron (or sometimes cast steel) cylinder of the same diameter as the shoe (generally between 8 and 9½ inches), and was typically from 16 to 20 inches long (Louis 1902: 177). One end of the cylinder was bored to receive the tapered end of the stem, and the other had a cast opening to receive the tapered shank of the shoe. Two drift-ways passed through the shoe so that the stem or shoe could be driven out using a tapered steel drift. These drift-ways were usually at right angles to each other (Figure 91). A hoop of wrought iron was sometimes shrunk around the top or bottom or both ends of the head to reinforce it (Louis 1902: 178; Raymond 1870: 658; Richards 1906: 185-186).
The Shoe

The shoe was the part of the stamp assembly that actually crushed ore against the die in the mortar box, and it was a wearing part so was regularly changed as it wore down. It consisted of a cast cylinder or butt on top of which was a truncated cone or pyramid shank (Figure 92). The shoe was mounted into the bottom of the stamp head by wedging the shank in a correspondingly shaped hole in the head, using thin wedges of timber to ensure a tight fit. These wedges swelled when wetted in the mortar box, and held the shoe securely.

Shoes were manufactured from a range of materials, including chilled cast iron, unchilled cast iron, high manganese cast iron, chrome steel, cast steel, Wilson’s pressed steel, fagot iron and manganese steel (Richards 1906: 182). The diameter of the shoes generally ranged from 8 to 9½ inches (up to 9 ¾ inches in Australia) (Richards 1906: 181). The relationship between the shoe diameter and the overall weight of the stamp assembly was important, as this determined the actual pressure exerted by the stamp. Louis (1902: 180) stated that a 900 lb stamp falling 6 inches would usually have a 9 inch diameter shoe, which would have an effective weight of between
14 and 11 lbs per square inch of crushing surface. For higher drops a slightly larger diameter could be used, but for a short 3 inch drop the diameter of even a heavy 1250 lb stamp should not exceed 9 inches (Louis 1902: 181). Figure 93 shows a range of shoes available from the Mine & Smelter Supply Co. (1912: 166).

![Figure 93. Stamp shoe and die sizes in the Mine & Smelter Supply Co. catalogue (1912).](image)

The height of new shoes ranged from 5½ to 10 inches, with 12 inch examples in use on the Rand in South Africa (Louis 1902: 181). The weight of the shoe varied depending on the size, but generally the range for new shoes was from 85lb to 198lb, with the large 12 inch deep 9 inch diameter shoes used on the Rand weighing 240lb (Louis 1902: 181; Richards 1906: 181).
Of this weight approximately 80% would be worn away before the shoe was discarded. The rate of wear depended on the material of the shoe and the nature of the ore being crushed, with a reported range of between 0.4lb and 1.5lb of iron lost per ton of quartz crushed (Louis 1902: 186; Richards 1906: 182; Schmitt, in contributed remarks p. 100 in Caldecott 1909). As discussed above, the stamp was rotated as it was raised, in order to even out the wear on the shoe and die. However, uneven wear did still occur, and could affect the stamp duty. At one stamp mill in Nevada in 1890 partially worn shoes were periodically refaced in a lathe, significantly increasing production (W.H. Shockley, contributed remarks p.89, in Caldecott 1909). Once the shoes were worn out they were discarded. The minimum thickness varied, with various authors stating a range between ¼ inch to 4 inches, but in general about 1 inch of remaining material was the practical limit (Louis (1902: 181; Richards 1906: 180).

The wear to the shoe had two main effects: it reduced the weight of the stamp assembly, and the drop height increased, exacerbated by the simultaneous wearing of the die. The increasing drop height needed to be addressed, or the falling tappet could hit the cam boss, causing breakage or excessive wear. The most direct method was to adjust the position of the tappets on the stem. A false bottom could also be inserted under the partially worn dies (see discussion below) to raise them and reduce the drop height.

The decrease in weight could be countered by the addition of compensating weights on the stamp shaft. The simplest and earliest method was to place an old head at the top of the stem or an additional tappet above the one in use, but better solutions that placed the weight lower down the stem were the use of a ‘false head’ or two-piece weights that could be bolted on the stem above or below the tappets (Caldecott 1909: 68; Del Mar 1912: 23). A ‘false head’ (or ‘chuck shoe’ or ‘false shoe’) was an extension piece that fitted in the bottom of the head, and into which the partially worn shoe was mounted (Louis 1902: 182).

**The Die**

The dies were the wearing parts on which the ore was crushed by the falling stamp assembly. Although they were mounted in the mortar box, they are discussed here as they worked directly against the stamp shoes. They were cast cylinders (Figure 94), usually of the same diameter as the shoe, although they could be up to ¼ inch larger in diameter to account for play in the stamper guides. They typically ranged in height from 3 inches to 7 ½ inches (Richards 1906: 179). The dies were held in place in the bottom of the mortar box either by circular sockets cast in the base of the box, by lugs on the side of the die, or by a square or octagonal foot plate cast on the die (Figure 94) (ILT 1902: 19; Louis 1902: 165; Richards 1906: 179).

![Figure 94. Two different die forms (ILT 1902).](image)

Dies were made from a variety of forms of iron or steel, including grey to mottled chilled iron, white chilled iron, unchilled cast iron, wrought iron, high manganese cast iron, cast steel, forged steel, chrome steel and manganese steel.

Like the shoes, the dies wore away as they worked, and were discarded once they were from ½ inch to 4 inches high (Richards 1906: 180). The conditions of wear for dies was slightly different to that of the shoes, as the dies were always covered by ore, so the rate of wear was generally less than that of the shoe (ILT 1902: 20; Louis 1902: 186). Some engineers used different materials for the shoes and dies in a mill, as it was thought better to allow the die to wear in preference to the shoe because of the relative ease of replacing the former over the latter (Del Mar 1912: 23). False bottoms could be inserted beneath partly worn dies in order to raise them and extend their life, although there was some question as to whether the use of a false bottom reduced the efficiency of a mill by reducing the solidity of the mounting of the die (Louis 1902: 167; Richards 1906: 180-181).
Chapter 6
Other Battery Processes:
Pre- and post-crushing treatment, other forms of crushing plant, gold recovery, power supply

This chapter discusses the other processes carried out within a battery; the pre-crushing breaking and post-crushing treatment of the ore; the recovery of gold bullion; and the power sources for the battery machinery. It also examines other forms of crushing plant that were used instead of stamp mills. There is less detail than was used in the discussion of stamp mills, as this chapter is meant to provide a more general background description to a wider range of plant and processes. There was ongoing development in these treatment processes, and some newer approaches supplemented or replaced older methods, an excellent example being the use of tube and roller mills that were used in the 1890s as a secondary grinding stage after stamps, but later replaced stamps altogether in many cases.

The treatment of the ore is organised into seven main sections: pre-treatment, sizing, crushing (other than stamp mills), gravity separation, mercury amalgamation, chemical treatments, smelting and power supply. The real world was never this simply divided up, and several different processes could be used in one plant. For example, both mercury amalgamation and cyanidation could be used in the same battery from the 1890s onwards. Some grinding machines were designed to simultaneously grind ore and amalgamate gold, and they are described below in the section on crushing and grinding machines. Although this places them before the detailed account of mercury amalgamation, it produces a logical flow in terms of discussing the physical reduction of ore in the milling process.

As this overall research is not intended to be an engineering history, but rather an archaeological investigation, the discussion below dwells more on plant and processes for which archaeological evidence still survives. Some historically widely used items, such as Frue vanners (a shaking table for concentrating crushed ore), have left very little evidence, and so these are only dealt with only briefly. Conversely, the cyanide process was an important innovation, and there is ample archaeological evidence of its use, so it is discussed in more detail.

Pre-treatment

Ore from a mine was transported to the battery where it might undergo several processes before being passed through a stamp mill. The simplest of these was sorting by size as lumps needed to be small enough to be fed through the mill. More complex were roasting processes intended to dry out, break up, or chemically alter the ore prior to crushing.

Ore Roasting

Ore roasting was the process where ore was placed in a furnace and heated to a high temperature to change its physical or chemical characteristics or simply to remove moisture. It should not be confused with smelting, where ore was heated to melting point to produce a matte that contained the economic minerals. Roasting could be carried out before or after crushing, or on the concentrates alone after crushing and separation had been carried out.
From the very start of hard-rock mining in New Zealand in the 1860s it was known that some local ores were difficult to treat, as Mining Surveyor Wright commented regarding quartz mining in the Wakatipu that ‘burning the pyrites is essential to the saving of the gold’ (OPC V&P Session XIX 1864: 12). Both before and after the introduction of the cyanide treatment (see discussion below) the roasting of ore was a common way of attempting to deal with refractory ores.

There were four basic forms of roasting; calcining, the oxidising roast, the reducing roast and the chloridising roast (ILT 1902 S30: 1-3). Calcining involved roasting the ore to drive off water and carbon dioxide, and to fracture the rock to make it more friable to assist crushing. The name of the process was probably based on the calcining of lime, as the first Victorian quartz roasting kilns were of the same design as lime kilns (Davey 1996: 55; Moore & Ritchie 1998: 45). The oxidising roast was intended to remove sulphides, arsenic and antimony in particular. As these interfered with gold recovery. By alternating between oxidising and reducing conditions, many of the volatile compounds of these materials could be driven off (ILT 1902 S30: 1). The chloridising roast was used in the chlorination process (discussed further below).

There were also differences in the way that fine ores (below ½ inch diameter) and coarse ores were handled, and different types of furnaces were used for their treatment. Fine ores were often roasted in reverberatory furnaces (Figure 95), revolving cylinders (Figure 96) and shaft furnaces, while coarse (lump) ores were roasted in heaps, stalls and shaft furnaces (ILT 1902 S30: 5, 26).

Figure 95. A hand-rabbled reverberatory furnace (ILT 1902).
Figure 96. The Howell-White furnace, an example of a revolving roasting cylinder (ILT 1902).

Battery House Processes

Figure 97 is a cross-section through a typical simple stamp mill, and shows the layout of some of the main items of plant that are described below. Considerably larger and more complex mills were built, but many of the basic processes were similar.

Figure 97. Cross-section through a typical stamper battery (ILT 1902 with annotations).
**Preliminary Sizing**

Ore delivered from the mine would be of random sizes, and on arrival at the battery hoppers it was poured onto a ‘grizzly,’ a set of parallel iron bars with a gap of between ½ and 3 inches between the bars, and inclined at 45° to 55° (Gordon 1906: 377; ILT 1902: S26: 9; Mine & Smelter Supply Co. 1912: 153). The size of this gap would control the size of the ore that could fall through into the hoppers and be fed directly to the stamps, and any lumps that were too large were fed to a rock-breaker to be reduced to a suitable diameter.

The degree to which ore should be broken down before being sent to the stamps was the subject of some discussion, with recommended sizes ranging from ½ inch to 2 inches diameter (Caldecott 1909: 59, 67; Del Mar 1912: 34; Gordon 1906: 377). The optimum size of the ore depended on a range of factors, including the nature of the rock and the weight of the stamps. One school of thought considered that breaking the ore too finely prior to milling was of little benefit, as the stamper worked most efficiently as an impact crusher on moderate sized lumps of ore, and if the ore fed into the mortar was too fine it would cushion the blow of the stamp (Caldecott 1909: 66-67). Some other grinders such as the Huntington Mill (discussed below) required quite finely broken ore, of about ½ inch diameter or smaller (ILT 1902 S25: 48).

**Rock Breaking**

The over-sized lumps of ore caught by the grizzly were sent to a rock-breaker to be reduced in size, and were then fed into the battery hoppers. Burt (2000: 326) has described the development of the rock crusher by Eli Whitney Blake in 1858 (for civil construction rather than gold mining) as being of worldwide impact, as it mechanised what had previously been a labour-intensive manual process. There were several common types and makes of breaker, including the Dodge, Blake-Marsden (Figure 98) and Samson jaw crushers, and the Gates gyratory crusher (Gordon 1906: 377; Mine & Smelter Supply Co. 1912: 154-158). The former three used a reciprocating jaw, while the latter used a fixed outer circular jaw with an internal revolving circular jaw (Gordon 1906: 377). Different sizes of machines were available for different capacities, and the larger Blake crushers could handle up to 250 tons of stone an hour (Mine & Smelter Supply Co. 1912: 154).

*Figure 98. The Blake rock breaker (Mine & Smelter Supply Co. 1912).*
Ore-Feeders

From the hopper ore was fed into the stamp mill either by hand or by an automatic ore feeder. The correct constant feeding of ore was important to maintain the appropriate depth of ore over the dies at all times, and hand feeding was generally found to be inconsistent and unsatisfactory (Gordon 1906: 378; Louis 1902: 269). The self-feeder was pioneered in California, the first example reputedly being invented by C.P. Stanford of San Francisco in 1859 (Paul 1895: 529). A number of other designs were subsequently produced (Figure 99), including the Challenge, the Tulloch, the Victor, the Stanford and the roller feeder, of which the Challenge had become the most commonly used form by the early twentieth century (Del Mar 1912: 124; Gordon 1906: 379; Louis 1902: 270, 273). The Challenge ore feeder was invented by Thomas Cockran of Tuolumne County, California, and first produced by the American firm of Joshua Hendy (Louis 1902: 273; Paul 1895: 529-530).

Figure 99. The Challenge, Roller and Tulloch ore feeders (Gordon 1906).

The Challenge ore feeder consisted of a small metal hopper above a revolving iron plate. A feeder arm was set under a striker on the central stamp stem, and each time the stamp fell and struck this arm it rotated a friction wheel on the feeder, which in turn was geared to rotate the feeder plate. This drew a small amount of ore from the hopper and directed it into the mortar box feed chute. The ore feeder could either be mounted in a wooden or metal frame that sat on the feeder floor, or suspended from above leaving the floor clear.

The Crushing Stage

From the ore feeder the ore went into the crushing mill. Several alternative forms of crushing mill to the stamp mill were used in New Zealand, including side rollers, parallel rollers, centrifugal rollers, grinding pans, and tube and ball mills. Heavy drag-weight grinders such as the arrastra were used in America and some other goldfields, but do not appear to have been widely adopted in New Zealand, although there are occasional references to their use (eg. Ulrich 1875: 87)

Early milling practice, prior to about 1900, was to use a single crushing stage of stamps alone, but in the early twentieth century coarse crushing in the stamp mill with a secondary crushing in another type of mill became more widespread, as this allowed the throughput of the stamps
(the stamp duty) to be increased (Caldecott 1909: 70). Tube or ball mills were usually employed for this secondary crushing purpose, but various types of grinding pans were also used (Caldecott 1909: 70; Gordon 1906: 415). Mills such as the Huntington Mill could be used for either primary or secondary crushing, depending on the nature of the ore being milled and the overall design of the battery. Many grinding and crushing mills could also be used for mercury amalgamation, and were often described as amalgamating machines, particularly when their amalgamation role was combined with a secondary rather than primary crushing/grinding role (see Gordon 1906: 414-418).

**Roller Mills (side rollers)**

![Image of side rollers](image1)

Side rollers (or radial rollers) used two or more heavy rollers mounted radially on axles from a central spindle (ILT 1902 S25: 44). The roller assembly was rotated inside a pan, and the rollers crushed ore fed in beneath them (Figure 100). The process relied on the weight of the rollers, and those installed at Ferguson’s New Era Works in the Waiorongomai Valley in 1885-86 weighed 2 ½ tons each (AJHR 1887 C5: 72).

**Figure 100. Cross-section of slow-speed Chilean Mill (Truscott 1923).**

**Roller Mills (parallel rolls)**

Parallel roll mills had a pair of revolving metal rollers set close together, and ore was fed between them to be crushed. In contrast to the side rollers described above, these mills did not depend on the weight of the rollers to crush the ore, but rather the distance between the rollers, which could be adjusted to suit the ore at hand. The idea was simple and direct, but in practice it was found that roller crushers wore unevenly (particularly in the centre) and required frequent expensive replacements (Gordon 1906: 414; Jack 1984: 21). Various designs of roller crusher were manufactured and used, which could be divided into three main classes: Cornish rolls, Cyclone rolls and Krom’s rolls (Gordon 1906: 413). The ‘Cyclone’ crusher of the late 1880s is illustrated in Figure 101.

**Figure 101. The Cyclone roller quartz crusher (AJHR 1888 C5).**
Centrifugal Roller Mills: The Huntington Mill

Centrifugal roller mills used a rotating set of rollers within an iron housing. There were several different designs of centrifugal roller mill, such as the Griffin Mill and the Huntington Mill, of which the latter was used by a number of New Zealand mining companies, the first being installed at Nenthorn in Otago in 1889 (AJHR 1890 C3: 59).

The Huntington Mill consisted of an iron pan with a central shaft that carried a ring from which three stems were suspended, each of which was fitted with an iron roller (Figure 102). The shaft was rotated at between 50 and 85 RPM, and the rollers were pressed outwards by centrifugal force against a circular die mounted in the bottom of the pan. Ore fed into the mill was thrown outwards against the die, and crushed between the die and the rollers. Mercury was placed in the mill, and there was a gap between the rollers and the bottom of the pan of about ½ inch to 2 inches for the amalgam to accumulate (Gordon 1906: 411; Gowland 1914: 207-208; ILT 1902 S25: 48-49). Screens were situated around the periphery of the mill, allowing the pulp to run out. The Huntington Mill could be used for primary crushing of ore after sizing, or for secondary crushing of intermediate pulp or tailings. The mill came in three sizes; 3 ½ feet, 5 feet and 6 feet diameter (ILT 1902 S25: 49).

The Huntington mill had several advantages over stamp mills in that it was cheaper to purchase and set up, was better for soft ores, and was better for regrinding coarse tailings, but it was also less reliable, not suitable for very hard ores and had a smaller throughput (Gowland 1914: 208).

Figure 102. Cut-away drawing of a Huntington Mill (ILT 1902).
Grinding & Amalgamating Pans

Grinding pans were secondary grinders, and were used to process ore that had already been coarsely crushed in a stamp or other mill. The grinding pan was an iron vessel about 5 feet in diameter and 2 to 3 feet deep, within which ore was ground between a fixed ring die and a rotating muller that was fitted with iron shoes (Figure 103). The clearance could be set by screw adjusters mounted on top of the yoke (ILT 1902 S27: 51; Truscott 1923: 95-96).

The basic form of grinding pan was the Wheeler Pan, and most other designs were derived from that pattern, and included the Railey Pan, Watson-Denny Pan and McKay Pan (Gordon 1906: 418; Truscott 1923: 97-99). The differences between some grinding pans and centrifugal roller mills were at times not large, and in some ways the technology could be regarded as a continuum. This was particularly the case with the McKay Pan (Figure 104), which used a set of discs running on top of the muller and against a ring die (Gordon 1906: 417).

Figure 103. Cross-section through a basic Wheeler Pan (Truscott 1923).

Figure 104. Cross-section through the McKay grinding and amalgamating pan (AJHR 1887).

When used simply for grinding it was necessary to place just ore and water in the pan, but when mercury amalgamation was also carried out more complex processes could be used. Steam-heating of the pulp to about 200° F (93° C) was sometimes carried out, either by direct injection of steam to the pulp or by using steam jackets on the pans (ILT 1902 S27: 52). Chemical additives could also be used, and the method used in some pan amalgamation plants in New Zealand was based on the ‘Washoe Process,’ that was in turn based on the ‘Patio’ process developed in Mexico in the sixteenth century (Gordon 1906: 418; Gowland 1914: 301; Gregory 1908: 101).
The pan was first charged with mercury, and then coarsely crushed ore, water and a little salt and copper sulphate was added. The pan was set in motion at about 65 RPM and steam was introduced to heat the mixture to about 210°F (99°C). The muller was lowered and the ore was ground for about 45 minutes, when more mercury was added. Grinding continued until it was judged that amalgamation was complete, and then the pulp was run out of the pan and into a separator (AJHR 1887 C5: 61). The separator (Figure 105) stirred the pulp and separated the amalgam from the slimes. A series of outlet pipes at different levels in the side of the separator allowed the waste material to be run away (Gowland 1914: 302). The amalgam was then collected and processed.

Figure 105. Cross-section of separating pan (AJHR 1887).

Figure 106 shows the pan grinding and amalgamation plant at Ferguson’s first New Era Works in the Waiorongomai Valley.

Figure 106. Ferguson’s New Era Works, Waiorongomai Valley (AJHR 1887 C5).
The Berdan

The Berdan pan was a grinding pan in which the pan itself rather than a muller was rotated, and was designed by Hiram Berdan of New York. His first machine was exhibited in 1852, and the design was patented in 1853 (Berdan 1853; Davey 1996: 57). Berdan pans were in use in California and North Carolina in 1853, in Victoria by 1855, and in New Zealand in 1862 (Davey 1996: 57; Hawkes Bay Herald, 8th July 1862: 2; Lyttelton Times, 8th August 1855: 5). It is of note that the original patent (Figure 107) included provision for a fire beneath the pan to heat the mercury, but this was not mentioned in later references (Berdan 1853).

Figure 107. The original US Patent drawings of the Berdan grinding and amalgamating pan (Berdan 1853).

The Berdan pan was usually 3 feet 6 inches to 4 feet in diameter, made from cast iron with a central spindle, was set at an angle, and contained an iron ball or drag that ground the ore as the pan rotated at 24 to 28 RPM (Gordon 1906: 415; ILT 1902 S28: 8). It was commonly used for further grinding and amalgamation of tailings and concentrates, although some authors described it simply as a clean-up pan for processing amalgam (ILT 1902 S28: 8). Although widely adopted in Australia and New Zealand, the Berdan had drawbacks; in particular it tended to flour the mercury (Gordon 1906: 415). Gordon (1906: 415) commented in 1906 ‘these machines are crude appliances for saving bullion, and the day is not far distant when their use will be discontinued.’ A number of later authors, such as Truscott (1923) and Wiard (1915), did not even mention the Berdan. Menghetti (2005: 207) suggests that the Berdan was out of favour in America by 1879, and was ‘ignored in Europe.’
**Ball & Tube Mills**

Ball and tube mills were machines in which the crushing was done by means of balls or flints rolling in a cylinder, and they were widely used in the cement industry as well as mining (ILT 1902 S25: 52; Lynch & Rowland 2005: 107). An early type of ball mill, the Otis Crusher, was in use in Marlborough in 1894 (Johnston 1992: 468), and tube and ball mills became widely used in the twentieth century for both primary and secondary crushing, at they at first supplemented and then largely replaced the use of stamps (Caldecott 1909: 70; Lynch & Rowland 2005: 56). There were a number of different designs, including the Krupp, Alsing and Allis-Chalmers mills.

The basic form consisted of a metal cylinder or drum with its axis horizontal, and fitted with hollow trunnions to allow ore to be introduced at one end and the pulp discharged at the other (Figure 108). Hardened internal wear plates were fitted to the inside of the mill. Tube mills containing hard flints tended to be long (up to 20 feet), while ball mills containing metal (iron or steel) balls were generally shorter (5 to 7 feet long) (ILT 1902 S25: 54-56; Truscott 1923: 111-122). When the mill was rotated and ore fed in, the falling balls/flints crushed by impact as well as ground by abrasion, reducing the ore to a fine pulp. The balls or flints themselves also wore, and would periodically require replacement.

![Figure 108. Cross-section of a typical tube mill (Gowland 1914).](image)

A modification to the general form of the mill was the Hardinge Conical Mill that was developed in the first decade of the twentieth century (Figure 109). The outlet end of this mill was cone-shaped, which was intended to concentrate the larger balls doing the coarse crushing at the largest diameter of the mill (where the peripheral speed was greatest), with the smaller balls doing the finer last grinding near the outlet where the diameter had been reduced (Truscott 1923: 125).
Post crushing Ore Treatment

Once ore had been crushed to the desired fineness, a number of gravitational and/or chemical processes were used to recover the gold bullion before the tailings were washed away. Early stamper batteries used only simple gold recovery techniques, but it was known that in many cases large amounts of gold were being lost in the tailings, and over time more complex processes were developed to improve recovery rates.

There were four broad classes of gold recovery: gravity, mercury amalgamation, chemical solution, and smelting. In many cases several different processes would be used in the same mill; for example, it was common to use amalgamating or blanket tables to catch the free gold from a mill, and then treat the tailings by cyanide to recover any remaining gold. Concentrates (the heaviest minerals) would sometimes be collected and sent to a smelter for further processing.

Gravity Separation

As described above in Chapter 3, the most basic form of gold saving was by gravity concentration. It was theoretically straightforward to separate gold from other minerals by gravity using blanket or riffle tables (described below). However, assay tests showed that this was not always successful, and much gold was lost. There were several reasons for this, including that the gold might not be fully freed from the gangue minerals, the gold particles were too fine and were washed away, and that the size of particles emerging from the crushing machine were not consistent which meant that simple hydraulic classification of crushed material would not necessarily separate heavy from light minerals. For these reasons, it was not only the gold that was collected, but also the ‘concentrates,’ the heavier mineral particles that were kept and then further processed.

Blanket & Riffle Tables

Inclined blanket or riffle tables were the simplest form of gold saving appliance used in stamper batteries, and relied solely on the high specific gravity of gold. Pulp from the
crushing plant flowed over the tables, and heavy material sank and was trapped in the weave of the fabric or behind the riffles, and lighter gangue minerals were carried away. The fabric used on blanket tables included cotton duck, woollen blanket, cocoa matting and carpet (Richards 1903: 700-703). Riffles were thin timber strakes set across the flow of the pulp, although other materials such as expanded metal riffles were also used (Richards 1903: 721-722). The tables were generally the same width as the mortar box outlet, but their length varied considerably, from 12 to 20 feet not being unusual but extremes of between 3 and 42 feet being recorded (Louis 1902: 342; Richards 1903: 703). The inclination of the tables varied depending on the proportion of water to the pulp, the fineness of the pulp, and the proportion of heavy minerals in the pulp. The recommended inclination was from 1.5 to 2.5 inches per foot (12.5% to 20%), but extremes of 5/8 inch to 3 inches per foot were used (Liddell 1945: 305). The fabric was regularly lifted from the tables and washed out in a tub to remove the collected concentrates, which would then be treated by a variety of methods depending on their nature, including simple panning, further grinding and amalgamation in a Berdan, or smelting.

**Buddles**

Buddles also relied on separation by specific gravity, and were particularly good at treating slimes (very finely ground material). Round buddles were circular tables with a surface that sloped either out from, or in towards, the centre at a slope of 1 to 2 inches per foot (effectively a large shallow cone or funnel). Pulp was fed in at the high point (the centre in an outward flow buddle), and as it flowed down the surface the heavier material (the heads) settled out first, the low-grade middlings second, and the lighter and barren tailings last. Rotating sweeps would ensure that the material was deposited evenly, and create riffles in the surface to catch descending heavier material. In this way the contents of the pulp became distributed across the buddle surface in bands that corresponded to their specific gravity, and could then be easily dug out and further processed (heads and middlings) or discarded (tailings) (Gordon 1906: 458-460; ILT 1902 S26: 39).

Davey (1996) stated that the Museum of Victoria has German models of buddles (sweep tables), including one designed in 1854, and thought that these may have been how the design was introduced to Australia. Round buddles were also extensively used in the West Country tin mining industry in Britain (Figure 110), where they were introduced in Dartmoor in the mid-nineteenth century and were still being constructed as late as 1927 (Greeves 2001: 32, 51, 60-62, 77, 79; Harris 1972: 35).

**Figure 110.** An outward-flow (convex) buddle in Devon in about 1912 (Greeves 2001).
Vanners & Shaking Tables

There were a number of designs of concentrators that relied on the principle that gold (and other heavy minerals) could be separated from lighter gangue minerals by agitating the crushed pulp in water and letting the lighter material run away with the flow of water. The shaking action that achieved the separation was called ‘vanning,’ and it was developed from the simple use of a shovel blade held horizontally and agitated while containing crushed ore and water (Pryce 1778: 216, 330). This process was mechanised by the development of moving-belt vanners and shaking tables, where the surfaces were mechanically shaken and a flow of pulp was separated, with the heavier concentrates and lighter gangue minerals leaving the machine in different places. Some authors regarded all shaking concentrators as vanners (eg ILT 1902 S27: 5-6), while others defined vanners as belt machines (eg. Truscott 1923: 350).

Moving Belt Vanners; the Frue Vanner

The moving-belt vanner was equipped with an endless belt that formed the shaking surface, which was set at a slight inclination. The drag of the belt took the heavy minerals to the upper end of the machine, while a flow of water washed the lighter minerals to the other end. The first moving belt design was developed in Scotland by William Brunton in the 1840s, and in some subsequent German mills it was given a ‘slight end percussive motion,’ but it was found that the belts were not sufficiently durable (Burt 2000: 327; Davies 1894: 317-319).

Between 1872 and 1874 William Bell Frue of Ontario considerably improved Brunton’s design by adding a secondary side-shaking motion (Davies 1894: 320; Burt 2000: 327; Newell 1985: 807). The Frue Vanner (Figure 111) used a wide endless rubber and canvas belt running over a set of rollers, set at a slight slope of 16 inches fall over the 12 feet length of the machine (AJHR 1887 C5: 71). The Frue Vanner was introduced to Victoria from California in about 1880 (Davey 1996: 58), and was also widely used in New Zealand. A number of other vanner designs, including the Union, Triumph and Luhrig vanners, all operated on similar principles and were probably based on the Frue design (Gordon 1906: 455-456; Truscott 1923: 350).

![Figure 111. Frue Vanner (Gordon 1906).](image-url)
**The Wilfley Table**

The surface of shaking tables remained stationary apart from the shaking motion. The most popular shaking table was the Wilfley Table (Figure 112) that was patented by the American engineer Arthur Redman Wilfley in 1897, and soon superseded the Frue vanner as a favoured concentrating machine (Burt 2000: 327; Wilfley 1897). It consisted of a roughly rectangular table, 12 to 16 feet long and 5 to 7 feet wide (slightly tapered towards the lower end), covered with linoleum and with a series of thin timber riffles fixed along its length (Gordon 1906: 456; ILT 1902 S27: 6; Truscott 1923: 362). It was set at a slight downward slope, and pulp and water was fed onto the table at the high end. The table motion had a forward movement and a backwards jerk, at a rate of about 240 reciprocations per minute, which agitated the pulp, and the heavy concentrates sank quickly behind each riffle while the lighter gangue minerals stayed in suspension and were washed away. As a result the pulp was separated on the basis of its specific gravity, and different minerals and exited the table at different points, allowing the valuable concentrates to be easily collected (ILT 1902 S27: 6-8; Truscott 1923: 362-366).

![Figure 112. The Wilfley Table (Mine & Smelter Supply Co. (1912)).](image)

**Mercury Amalgamation**

The basic principal of mercury amalgamation was discussed above in Chapter 3. The process involved using mercury to recover gold by forming an amalgam that could then be treated to recover the bullion. It could be carried out in a number of ways. As discussed above in Chapter 5, free mercury and/or amalgamating plates were sometimes used inside stamp mill mortar boxes, meaning that some gold was amalgamated before the pulp had even left the stamps, or complete reliance could be placed on the outside amalgamation plates in front of the stamps (Liddel 1945: 303). As discussed in detail above in this chapter other crushing mills, such as the Huntington Mill, could also be used for both crushing and amalgamation
Whether or not inside amalgamation was employed, the pulp would still require treatment after it passed from the crushing machine.

After passing through the mortar box screen, the simplest arrangement was for the pulp to pass straight across an amalgamating table (Figure 113). Amalgamating tables were set up in a similar fashion to blanket and riffle tables. Gordon (1906: 388) writing in the New Zealand context suggested the table should be from 10 to 12 feet long and fall at 1 to 1 ¾ inch to the foot, while Gowland (1914: 203) suggested 6 to 15 feet long with a slope of ½ inch to 2 ½ inches to the foot. The tables sometimes had steps in them, where the pulp would fall up to 12 inches from the foot of one table to the head of the next.

The tables were faced with copper or muntz metal (60% copper 40% zinc alloy) plates, which were sometimes electroplated with silver, and were then periodically coated with mercury (the silver plating assisted the adhesion of the mercury). As the pulp was passed over them the mercury would trap the gold that flowed over them, as well as amalgam that escaped the mortar box when inside amalgamation was practiced. Mercury troughs were sometimes placed at one or both ends of the tables to improve gold recovery and trap any loose amalgam. Periodically the plates would be scraped clean, the amalgam processed, and new mercury added.

Figure 113. Mercury amalgamating tables (Richards 1903).

As with many aspects of gold milling practice designs of tables changed over time, between places and between individual batteries. In 1909 Caldecott commented that ‘the whole tendency of amalgamation on the Rand (South Africa) has been to eliminate mercury wells, and steps or falls in plates, and to rely upon a single amalgamated inclined plane surface’ (Caldecott, author’s reply in Caldecott 1909). At the Energetic Battery near Reefton
particularly long tables were used to attempt to save as much gold as possible in the absence of any effective method of treating the tailings (Latham 1984: 191).

**Recovery & Processing of Amalgam**

Amalgamating tables would be regularly scraped and amalgamating machines cleaned out to recover the mercury/gold amalgam, and periodically a battery would undergo a more thorough clean-up, when the mortar and dies would be cleaned and the plates cleaned and redressed. The amalgam that was collected might require cleaning if it was contaminated with sand and other foreign particles, or if it was clean it would be processed as collected.

**Amalgamating & Clean-up Pans**

Clean-up pans were used to either clean up dirty amalgam or to process small quantities of heavy blanket concentrates with mercury. For cleaning amalgam wooden muller shoes were generally used, as their job was stirring rather than grinding, and extra mercury would be added to the dirty amalgam. Foreign matter would rise to the top and could be washed away by a flow of water. For grinding and amalgamating iron shoes were used (Gowland 1914: 204; ILT 1902 S28: 8). One of the functions of these pans was to abrade and clean the surface of gold particles allowing them to amalgamate with the mercury. The Berdan was commonly used for this purpose.

**Clean-up (Amalgamation) Barrels**

Clean-up barrels were used to process dirty amalgam in a similar fashion to clean-up pans. The barrels could be made from wood or iron, and measured about 4 feet long and 2 to 3 feet in diameter (Gowland 1914: 204; ILT 1902 S28: 8). They were mounted on trunnions so that they could be rotated (Figure 114). The barrel was charged with amalgam and extra mercury, water, and sometimes scrap iron such as iron balls and pieces of broken stamp stems, and then rotated at about 20 revolutions per minute for about two hours. The barrel was then emptied and the amalgam recovered, strained and retorted (Gowland 1914: 204; ILT 1902 S28: 8-9).

**Figure 114. A clean-up (amalgamating) barrel (Mine & Smelter Supply Co. 1912).**

**Processing of Mercury Amalgam**

Once the clean amalgam had been gathered it would be placed in a chamois leather or canvas bag and squeezed to remove excess mercury. In some mills an amalgam strainer and safe was employed (ILT 1902 S28: 26). This consisted of a cast iron conical dish with a covered hole in the centre mounted on top of an iron body that contained a canvas bag or strainer (Figure
Amalgam poured into the dish would pass into the bag, and the excess of mercury in the amalgam would strain through to be collected in the base of the iron body, while the canvas bag held the dry amalgam that could then be retorted. The body of the strainer could be locked to prevent theft of the amalgam.

**Figure 115. Amalgam strainer and safe (ILT 1902).**

After the amalgam had been collected and excess mercury strained off, the dry amalgam would be placed in a sealed iron retort (Figure 116) that was then heated to the boiling point of mercury (360°C). At this temperature the mercury would vaporise and escape through an outlet pipe where it would be recovered in a water-cooled condensing tube, and the gold would be left behind in the retort (Gowland 1914: 347-348; ILT 1902 S27: 39-40). The retorted gold would generally then be melted and cast into an ingot.

**Figure 116. Mercury retort and condensing tube (ILT 1902).**

**Problems with Mercury Amalgamation**

Although mercury amalgamation was effective, there were still many potential losses of both amalgamated and unamalgamated gold. Some of the main losses were (from Gowland 1914: 206):

- Loss of gold in floured mercury.
- Mechanical losses of amalgam.
- Coarse particles of ore containing gold being washed away.
- ‘Float’ gold (ie, very fine particles of gold that floated and were washed away).
- ‘Rusty’ gold that was coated with another mineral substance and resisted amalgamation.
- Loss in pyrites and tellurides.
- Loss in tailings.
Of these issues, flouring and sickening of mercury were the main problems. Flouring occurred when mercury was reduced to excessively small particles (that resembled flour) due to excessive stamping, and when in this state the particles would not coalesce or take up gold. Sickening occurred when mercury became coated with a substance that prevented it from amalgamating or coalescing, such as talc, manganese oxide, galena, arsenical pyrites, stibnite and grease (Gordon 1906: 420; Gowland 1914: 305; Liddel 1945: 303). It was for this reason that it was essential to prevent oil or grease from the stamp mill’s moving parts falling into the mortar box.

The loss of gold and mercury was known and understood by many mine and battery managers, but in many cases the means to improve the recovery rates were not available, or were so expensive as to make them uneconomic, until the cyanide process appeared in 1889. The reprocessing of battery tailings that had earlier been stockpiled or discarded was then commonly undertaken.

**Chemical Gold Recovery Processes**

The two main chemical gold recovery methods were chlorination and cyanidation, the latter of which was one of the single most important developments in the late nineteenth century gold mining industry (Burt 2000: 334-335; Jack 1984; Salmon 1963: 210; Todd 2009: 113).

**Chlorination & Lixiviation**

Chlorination dissolved the gold present in an ore using chlorine gas. Chlorine has a strong affinity for gold, and readily combines with it to form a soluble gold chloride that can be washed out of the treated ore using water. Gold is then recoverable from this chloride solution by precipitation (Gowland 1914: 208). ‘Lixiviation’ refers specifically to the process of solution and subsequent precipitation of a substance, but the term is not confined to the chlorination process. There were three main variations of the chlorination process, namely the vat process, the barrel process and the vat-solution process, but all followed five basic steps (Gowland 1914: 210):

- Crushing of the ore.
- Roasting with or without common salt.
- Chlorination and lixiviation.
- Precipitation.
- Conversion of the precipitate into bullion.

There were problems with the process. It did not suit ores that also contained lead or silver, and it was expensive due to the need to roast all ore in a furnace prior to treatment, and the chlorine gas was extremely toxic (Jack 1984: 22). Many chlorination plants were replaced by cyanide plants after the latter process was introduced, but chlorination continued to be used in some situations where it was found to suit local conditions.
**The Cyanide Process**

The cyanide process also involved dissolving gold in a solution, but it proved to be a far cheaper and more effective process than chlorination in most situations. The process used a weak solution of potassium cyanide to dissolve the bullion in crushed ore, and the bullion was then recovered by precipitation out of solution using zinc shavings. The process was relatively straightforward, did not require an expensive roasting stage (although roasting was sometimes carried out), and recovered a far higher proportion of the bullion (in most ores) than previously. Gold recovery rates went from less than 40% of the assay value to a reported 93% in the first year of work of the first plant in New Zealand (AJHR 1891 C4: 37). However, not refractory all ores were responsive, and the copper and lead sulphide ores at Te Aroha were one example where cyanidation was not effective (Salmon 1963: 219).

**New Zealand’s First Commercial Cyanide Plant**

The first main cyanide plant built at Karangahake in 1889 consisted of a series of large rectangular percolation tanks built from 4 inch thick kauri, each tank measuring 9 feet wide, 12 feet long and 3 feet 6 inches high (Figure 117). At the base of each tank was a filter bed consisting of layers of pebbles and sand. The tanks were charged with dry crushed ore, wetted as it was laid down with potassium cyanide solution applied from a watering can, with enough room left at the top for the potassium cyanide solution to be fed into the tank. The cyanide solution was allowed to percolate slowly through the ore for about 36 hours, and then passed quickly through the ore again, followed by a washing of water, after which the ore was discarded (AJHR 1890 C3: 38-39).

![Diagram of cyanide process](image)

**Figure 117. Cyanide tank and precipitating towers erected for the Crown Mine in 1889 (AJHR 1890 C3).**

The gold and silver was recovered from the charged potassium cyanide solution by precipitation, using zinc granules or zinc turnings contained in a series of barrel-shaped

---

24 It is unknown how accurate this figure is, given the gold industry’s historical reputation for inflated claims.
wooden precipitation towers (later cyanide plants used horizontal boxes, see Figure 119). The precipitate was recovered by washing out the zinc in a sieve, and it was treated with sulphuric or muriatic acid to dissolve any zinc residue, washed in hot water, dried and then smelted with suitable fluxes into bullion (AJHR 1890 C3: 38-39).

The Widespread Adoption of the Cyanide Process

The cyanide treatment was widely adopted after the New Zealand Government purchased the patent rights to the process and reduced the fees in 1897. The conventional cyanide plant consisted of a number of items of plant, including (from Gordon 1906: 468):

- A tank in which the cyanide is dissolved.
- A storage tank for holding strong solutions.
- Leaching or percolation vats.
- Zinc extractors.
- Storage vats.
- Sumps.
- Agitating vats.
- Vacuum cylinders and air pumps.
- Air compressor plant.
- Filter presses.
- Filter vat for washing and drying precipitates.
- Furnace.
- Assay office and laboratory.

The complexity and size of cyanide plants in use varied considerably, depending on the amount and refractory nature of ore to be treated. Figure 118 shows a plan and side elevation of a 75 ton per day capacity cyanide plant (Gowland 1914). This shows the basic layout, with solution tanks at the highest part of the system, with the leaching tanks, solution tanks, zinc precipitation boxes and sumps arranged below.

The cyanide process was a batch process, whereby the leaching vats (B) would be filled with pulp, and then cyanide solution would be added from the storage tanks (A). The solution would dissolve the bullion content in the ore, and then would pass to the gold solution tanks (C, D) and then through the zinc precipitation boxes (E, F) (see Figure 119) where the bullion would precipitate out of solution. The precipitate would then be washed out into the acid tank (L), and then collected and dried prior to smelting.
Figure 118. Plan and elevation of a 75 ton per day cyanide plant (Gowland 1914).
Cyanidation was generally used as a secondary process, after ordinary amalgamating or blanket tables. For example, at the Alexander Mine (West Coast) a cyanide plant was installed in 1926 to treat the battery tailings coming off the tables, and overall this produced some 20% of the gold won (AJHR 1933 C2: 30; Bolitho 1999: 80).

**Developments in the Cyanide Process**

The original McArthur-Forrest patent had been quite vague, and there were soon legal challenges in several countries to the patent. Other cyanide processes and patents appeared quite rapidly; for example, the Siemens-Halske process was developed in Germany in 1888, and employed electrolysis using a lead cathode and iron anode rather than zinc precipitation boxes (Gordon 1906: 479-480).

The B&M or Brown Agitator tank (also known as a Pachuca) was a successful New Zealand innovation (Figures 120 and 121). It was developed at Waihi and was named after C.F. Brown, the manager of the Grand Junction Battery. The B&M tanks were tall and thin (about 15 feet diameter and 50 feet tall), with a conical base into which a jet of compressed air was introduced. When the tank was filled with pulp and cyanide solution the compressed air both kept the mixture in circulation and provided an oxygen supply to assist the reaction (AJHR 1908 C3: 66; Gowland 1914: 245-247; McAra 1988: 141).

**Figure 120.** (Right) Cross-section of a Brown agitator (Gowland & Bannister 1930).
Figure 121. The Waihi Mining Company’s Brown (or B&M) agitator tanks at the Victoria Battery, Waikino (Gowland & Bannister 1930).

Re-Processing of Tailings

It was widely recognised that early treatment processes lost a great deal of gold, and the advent of the cyanide process presented the opportunity to profitably re-treat old tailings. Some battery managers had stockpiled tailings for possible later re-treatment, such as at the Golden Bar Mine in Otago and Big River Mine near Reefton (AJHR 1898 C3A: 15; 1905 C3: 59). However, in most cases the tailings had simply been washed away down the nearest stream of river (McCombie 1897: 34). In this situation the recovery was more difficult, but not necessarily impossible. In the Ohinemuri area two treatment plants were set up recover and treat these riverbed tailings. In 1903 the Ohinemuri River syndicate built a plant beside the Ohinemuri River, and in 1910 the Waihi-Paeroa Gold Extraction Company (Ltd) took over the operation and constructed a second plant downstream. In both cases the river sands were raised by a suction dredge, treated by the cyanide process and then discharged back into the river (Ritchie 1990: 265; AJHR 1913 C2: 20-21).

Smelting

Smelting of some of New Zealand’s refractory ores was attempted on a number of occasions. Smelting differs from roasting in that roasting involves the heating of ores to drive off sulphides in particular, while smelting involves melting the ore with various fluxes in order to produce slag (which should contain the gangue) and a matte (which should contain the bullion). Roasting was therefore an ore treatment, while smelting was a gold recovery process.

A number of smelters were constructed in the goldfields, with varying degrees of success. The Te Aroha Silver and Gold Mining Company’s Reduction works at the mouth of the Waiorongomai Valley was equipped with a water jacket furnace for smelting (AJHR 1890 C3: 44; Te Aroha News, 4 May 1889: 2). Two La Monte Furnaces were erected in 1885, one
at Thames and one at Karangahake, and while they did work and recover a reasonable proportion of gold present in the ore being treated, the expense of their operation made them uneconomic (AJHR 1886 C4A: 2, 12; Weston 1927: 103). In 1910 a blast furnace was built by the Tarawera Mining and Smelting Company in Preservation Inlet in Fiordland but a trial smelting in 1911 failed to make a return, and the smelter was shut down (AJHR 1912 C2: 55).

**Power**

Power was essential to drive mill machinery. Wherever possible gravity was used in the mining and milling process, and Gordon (1906: 374) recommended that in selecting a mill location “the site should be selected with regard the cheapest method of transporting the ore from the mine by automatic haulage and dumping it in the hopper at the highest point of the mill, so that in passing through all operations it may descend from one to the other by gravitation.” However, even allowing for a perfect geographical location for the mill relative to the mine, power was still required for driving the crushing and processing equipment.

The choice of power for any particular industrial enterprise depended on many factors, including the knowledge or experience of the people involved, the capital available, the amount of power required, fuel availability, the distance any equipment had the be transported, and the availability and/or cost of any machinery. The power choices available in the late nineteenth century can be divided up into a number of basic categories: animal, wind, water, steam, internal combustion and electricity.

**Animal & Man Power**

Horses remained in widespread use in mining and other industries well into the twentieth century. One common use was in whims (or gins), where a horse was harnessed to a shaft attached to a central pivot around which the animal walked. The pivot was either geared to a driveshaft that transmitted power to other machinery, or was attached to a drum around which rope was wound for hauling. Horses were of course not the only beast of burden, and cattlebeast in particular were widely used, especially for heavy haulage (Thornton 1982: 19).

The labour of men must also not be forgotten, as although the nineteenth century saw the emergence of heavy machinery, manual labour still played an important role in most industries. Many mines had a large workforce employed in underground, surface and battery work; for example, in 1909 at the peak of its production, the Waihi Mining Company had an average workforce of 1,120 men, despite being one of the most technologically advanced mining operations in the country (McAra 1988: 128-129). The role of the working man is explored further in Chapter 11 below.

**Wind Power**

Wind power is never constant, and there is no evidence that it was ever used to power stamp mills, although there are records of wind power being used for pumping in the mining industry (AJHR 1894 C3A: 39).
Water Power

Water power was often the power source of choice for mining operations, as it was cheap if a sufficient water supply was close and reliable. At Thames, when the water race from the Kauwearanga Stream was completed in 1878 many of the local batteries were converted from steam to water power (Weston 1927: 76). However, if the supply was distant then long water races and/or pipelines were required, and summer drought and winter freeze could halt operations.

Water power is derived from either the kinetic energy in flowing water or potential energy in water at a height. Hydraulic motors can be divided into three general classes (Oberg & Jones 1917: 446):

- Water wheels, which utilise either the impact of the current of the wheel or the weight of the water.
- Impulse wheels and turbines, which utilise the kinetic energy of a jet at high velocity. These are commonly employed in connection with a limited volume of water at a high head.
- Reaction turbines, which utilise both the kinetic energy and the pressure of the water. These are employed for conditions with a large volume of water under a low or medium head.

Waterwheels

Water wheels come in a variety of forms, which can be broadly broken down into two main categories: overshot, pitchback and high-breastshot wheels that utilise the potential energy of falling water; and low-breastshot and undershot wheels that utilise the kinetic energy of flowing water (Figure 122). The mountainous nature of many of New Zealand’s goldfields suited the use of the more efficient overshot and pitchback water wheels, with their characteristic tall and thin design (Petchey 1996: 83).

Figure 122. The three main types of water wheel (Oberg & Jones 1917). From the left; undershot, breastshot (high) and overshot.
Whitelaw Turbine

The Whitelaw (or Whitlaw) turbine was a basic form of reaction turbine that was patented by James Whitelaw in England in 1841 and the U.S. in 1843, and is considered to be the first true metal turbine water wheel (Clark 1897: 939-940; Johnson & O’Reilly 1978: 57-58). It was a refinement of the earlier Barker’s Mill, and consisted of two hollow curved radial arms revolving around a central hub through which the water supply was fed. It operated in a similar fashion to a modern water sprinkler, as the two jets of water drove the runner and its attached drive shaft around (Figure 123).

Figure 123. Plan and elevation of the Whitelaw Turbine (Glynn 1872).

Pelton Wheel

The Pelton Wheel was patented by the American Lester Pelton in 1880 (Williams 1996: 52). It was a development of the crude ‘hurdy-gurdy’ impulse wheels that had been used with a jet of water directed at flat paddles or buckets. In California in the 1860s and 1870s various mechanics had experimented with curved buckets, but Pelton’s great achievement was to place a splitter in the middle of the bucket (Figure 124), that cleanly split the flow of water and avoided loss of energy through turbulence.

Figure 124. Simplified side elevation and plan of the Pelton Wheel (Oberg & Jones 1917).

The Pelton Wheel had been designed in the Sierra Nevada of California where high-head low-flow water supplies were available, and was therefore ideally suited to New Zealand where the same conditions often existed (May 1969: 67; Williams 1996: 51-52). The first Pelton wheel in New Zealand was probably that erected by G.W. Bull at Hape Creek near Thames in
1883 or 1884, which he had constructed after an account of a trial in Idaho was published in the *Californian Scientific Press* (AJHR 1884 H9: 3). The engineering company A.&G. Price of Thames obtained the New Zealand rights to manufacture the wheel in 1884 (Vennell 1968: 16).

![Pelton wheel in timber frame with timber housing](image)

**Figure 125.** Pelton wheel in timber frame with timber housing (Mine & Smelter Supply Co., 1912).

### Steam Engines

Steam engines provided a reliable and controllable power source, and were widely adopted in all industries. By the time the New Zealand goldfields were in operation small and reliable steam engines were easily available from manufacturers in England, Australia, America and New Zealand.

One of the drawbacks of steam engines was that they required large amounts of fuel. In 1899 the Waihi Gold Mining Company was using 1,000 tons of firewood a month to run the pumps at No. 1 and 2 shafts (McAra 1988: 113). Coal was more efficient (depending on the quality of both, 3.5 tons of coal would do the same work as approximately 20 tons of firewood), but required transport from a suitable coal mine. In some places coal measures were found near gold reefs, such as around Reefton, where steam power was used extensively, but as commented upon above, in areas such as Thames the advent of reliable water supplies saw a general switch from steam to water power whenever practical.

### Internal Combustion Engines

Internal combustion engines became a popular choice of power in the twentieth century, although the fuel was often expensive. Gas engines used that coal gas produced in a gas generator were used at a number of stamp mills, such as the Golden Bar Battery (AJHR 1928: C2: 25), but these still required a coal supply. The Alexander Mine (near Reefton) used a
petrol engine for a period in the mid-1920s, but the expense of the petrol meant that the mining company switched back to water power (AJHR 1928 C2: 23).

**Electric Power**

Electric power could be generated at the most convenient place and then taken by power cable to wherever it was required, which was a great advantage in New Zealand’s often mountainous goldfields. The gold mining industry played a particularly important role in the large-scale development of electric power generation in New Zealand, as the Phoenix Mining Company’s electrical installation at Bullendale in Otago in 1885/86 is regarded as the country’s first industrial hydro-electric plant and power transmission line (Reilly 2008: 17). The electrical equipment was manufactured in England by the Anglo-American Brush Corporation, and motive power was supplied by two Pelton Wheels manufactured by Price & Sons of Thames in New Zealand (AJHR 1886 C4: 19; 1887 C5: 46; Wilson 1916: 276).

Subsequently many other mining companies adopted electric power, culminating in the decision in 1910 of the Waihi Gold Mining Company to build what was at the time the country’s largest hydro-electric power station at Horahora on the Waikato River (Rowe & McKey 1997).
Chapter 7

The Archaeological Survey:
Sample Size, Taphonomy, Bias, Site Survey Methodology

This thesis is based on the examination of 83 stamp mill sites, 13 relocated stamp mills and 4 other gold processing sites located throughout New Zealand’s historic goldfields (Figures 126 to 129). The areas of the greatest historically recorded numbers of stamp mills were the Hauraki/Coromandel, Nelson, West Coast and Otago/Southland regions, and this is reflected in the modern archaeological record.

Figure 126. Locations of North Island sites.
Figure 127. Locations of South Island sites.
Figure 128. Locations of sites in the Reefton area, West Coast.

Figure 129. Locations of sites in the Skippers and Macetown areas, Otago.
Sample Size & Representativeness

This research was started in the full knowledge that the surviving stamp mills in the New Zealand archaeological record were highly unlikely to provide a full and representative sample of the stamp mills that had once existed. In particular it was already known that New Zealand’s largest mills, such as the Victoria Battery at Waikino (200 stamps) and the Crown Battery at Karangahake (60 Stamps) were stripped of their machinery when they closed. Most surviving mills range from 1 stamp to 15 stamps in size, with only two remaining examples of 20 stamp mills (Johnston’s United and Taitapu in NW Nelson). The archaeological sample discussed here is therefore unavoidably skewed towards smaller mills, while as White (2010: 66) has discussed for the American situation, much contemporary literature is biased towards larger mills. Some of the larger mill sites (such as the Victoria and Snowy River Batteries) are included in the archaeological sample, but observations on their machinery are largely limited to the foundations and a few loose parts. In the case of the Victoria Battery it is possible that one bank of 5 stamps has survived and is in the collection of the Hauraki Prospectors’ Association in Thames (Ritchie 1990: 103), and this has allowed some investigation into this mill.

It is not known exactly how many stamp mills have existed in New Zealand, but examination of the Machinery Returns in the annual Mines Reports (published in the AJHR) shows that at any time during the period covered (1872 to 1909, with incomplete 1860s information) there were often more than 40 machines at work in the Auckland Province, 25 in the Nelson Province and 30 in the Otago Province, and that in any one year during the 1880s, 1890s and 1900s between 90 and 140 machines were at work in the country (Table 11). It is not possible to estimate the total number of stamp mills that have existed by simply adding up the yearly totals in this data, as in each year some machines would have continued working, some would have ceased work, and new machines would have been built. However, by looking at listings at 20 year intervals (89 machines in 1872, 97 in 1890 and 109 in 1909) and by assuming that in each interval many (although certainly not all) batteries would have been replaced within that period, at least 300 stamp mills would have operated in New Zealand between 1872 and 1909. Pre-1872 and Post-1909 battery sites are harder to quantify because the collated contemporary information does not exist, but the Thames Gold Fields Miners’ Guide of 1868 lists 40 machines at Thames, while the current research identified 24 post-1909 mills incidentally, without any particular attempt to quantify machines from this period. This would suggest that the total number of battery sites for the whole history of the New Zealand goldfields would be nearer 500 than 300.

It is also important to remember that because many stamp mills were moved and re-erected, sometimes several times over, there will be many more battery sites in the country than there ever were actual machines. Attempting to quantify the number of machines is virtually impossible, especially as some were created by combining parts from several earlier mills, and were later split up to be recombined into later mills. The New Zealand Archaeological Association Site Record File (Archsite) includes some 170 battery sites (in February 2013). Based on the discussion above, it is probable that about one third of the total number of battery sites that have existed have been recorded, although it is likely that most sites with substantial surviving machinery have been included.

---

25 The information published in these annual returns is known to have some errors, a glaring one being the listing for 200 machines at work in Nelson in 1889. However, it is the only source for this type of information, and is probably generally correct if not specifically accurate.
Table 11. Stamper battery numbers 1863-1909.
The numbers of stamper batteries (machines) and total number of stamp heads for the main mining provinces between 1863 and 1909 as recorded in the machinery returns in the annual Mines Reports (AJHR 1863-1909). Note that there are errors in this list, the most glaring being the record of 200 machines in Nelson in 1889. Mach = number of machines, Head = total number of stamp heads.

<table>
<thead>
<tr>
<th>Year</th>
<th>Auckland Mach</th>
<th>Wellington Mach</th>
<th>Marlborough Mach</th>
<th>Nelson Mach</th>
<th>West Coast Mach</th>
<th>Otago Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Head</td>
<td>Head</td>
<td>Head</td>
<td>Head</td>
<td>Head</td>
<td>Head</td>
</tr>
<tr>
<td>1863</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1864</td>
<td>4</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1865</td>
<td>4</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1866</td>
<td>4</td>
<td>(30+)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1872</td>
<td>70</td>
<td>891</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>1873</td>
<td>11 (?)</td>
<td>881</td>
<td>14</td>
<td>135</td>
<td>23</td>
<td>199</td>
</tr>
<tr>
<td>1874</td>
<td>56</td>
<td>930</td>
<td>10</td>
<td>11</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td>1875</td>
<td>54</td>
<td>938</td>
<td>10</td>
<td>10</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>1876</td>
<td>50</td>
<td>908</td>
<td>15</td>
<td>184</td>
<td>22</td>
<td>192</td>
</tr>
<tr>
<td>1877</td>
<td>53</td>
<td>987</td>
<td>14</td>
<td>193</td>
<td>19</td>
<td>164</td>
</tr>
<tr>
<td>1878</td>
<td>51</td>
<td>960</td>
<td>32</td>
<td>218</td>
<td>23</td>
<td>188</td>
</tr>
<tr>
<td>1879</td>
<td>43</td>
<td>788</td>
<td>10</td>
<td>16</td>
<td>218</td>
<td></td>
</tr>
<tr>
<td>1880</td>
<td>48</td>
<td>687</td>
<td>10</td>
<td>18</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>1881</td>
<td>43</td>
<td>619</td>
<td>10</td>
<td>19</td>
<td>253</td>
<td></td>
</tr>
<tr>
<td>1882</td>
<td>43</td>
<td>629</td>
<td>10</td>
<td>19</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>1883</td>
<td>44</td>
<td>639</td>
<td>10</td>
<td>22</td>
<td>288</td>
<td></td>
</tr>
<tr>
<td>1884</td>
<td>44</td>
<td>639</td>
<td>27</td>
<td>331</td>
<td>21</td>
<td>214</td>
</tr>
<tr>
<td>1885</td>
<td>35</td>
<td>526</td>
<td>25</td>
<td>300</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1886</td>
<td>31</td>
<td>573</td>
<td>26</td>
<td>359</td>
<td>20</td>
<td>238</td>
</tr>
<tr>
<td>1887</td>
<td>31</td>
<td>563</td>
<td>28</td>
<td>374</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1888</td>
<td>32</td>
<td>565</td>
<td>29</td>
<td>385</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1889</td>
<td>29</td>
<td>545</td>
<td>200</td>
<td>443</td>
<td>47</td>
<td>98</td>
</tr>
<tr>
<td>1890</td>
<td>29</td>
<td>558</td>
<td>34</td>
<td>427</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>1891</td>
<td>42</td>
<td>599</td>
<td>32</td>
<td>437</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>1892</td>
<td>45</td>
<td>486</td>
<td>1</td>
<td>33</td>
<td>458</td>
<td></td>
</tr>
<tr>
<td>1893</td>
<td>49</td>
<td>654</td>
<td>1/10</td>
<td>33</td>
<td>459</td>
<td>1</td>
</tr>
<tr>
<td>1894</td>
<td>57</td>
<td>631</td>
<td>1/10</td>
<td>48</td>
<td>410</td>
<td>1</td>
</tr>
<tr>
<td>1895</td>
<td>51</td>
<td>718</td>
<td>20</td>
<td>30</td>
<td>430</td>
<td>2</td>
</tr>
<tr>
<td>1896</td>
<td>48</td>
<td>777</td>
<td>2</td>
<td>10</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td>1897</td>
<td>36</td>
<td>808</td>
<td>2</td>
<td>10</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>1898</td>
<td>22</td>
<td>1004</td>
<td>1</td>
<td>10</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>1899</td>
<td>34</td>
<td>1035</td>
<td>1</td>
<td>10</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>1900</td>
<td>47</td>
<td>1957</td>
<td>1</td>
<td>10</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>1901</td>
<td>38</td>
<td>1348</td>
<td>1</td>
<td>10</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>1902</td>
<td>59</td>
<td>1462</td>
<td>2</td>
<td>10</td>
<td>36</td>
<td>5</td>
</tr>
<tr>
<td>1903</td>
<td>23</td>
<td>1187</td>
<td>2</td>
<td>20</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>1904</td>
<td>15</td>
<td>1280</td>
<td>2</td>
<td>20</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>1905</td>
<td>44</td>
<td>1300</td>
<td>2</td>
<td>20</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>1906</td>
<td>46</td>
<td>1300</td>
<td>2</td>
<td>20</td>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>1907</td>
<td>66</td>
<td>1330</td>
<td>2</td>
<td>20</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>1908</td>
<td>73</td>
<td>1378</td>
<td>1</td>
<td>10</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>1909</td>
<td>62</td>
<td>1220</td>
<td>2</td>
<td>20</td>
<td>19</td>
<td>7</td>
</tr>
</tbody>
</table>

The sample of 100 archaeological sites and machines discussed in this thesis is therefore a reasonable sample of the mills that once existed (approximately 20%), and even if the ca. 500 estimate of sites that have existed is 100% too small, the sample size drops to 10% which is
still reasonable for an archaeological assemblage. However, while the coarse numbers look acceptable, the presence of bias in the archaeological assemblage has already been identified, and the factors that have affected the survival of these mills need to be understood so that any observations and conclusions based on the archaeological evidence can take into account the differential preservation of the machinery.

**Taphonomy, Site Survival & Sources of Sample bias**

Stamp mills were large and robust pieces of machinery, designed to operate in a harsh environment. However, after any particular mill closed, many different processes affected if and how it survives to the present day. Figures 130 and 131 show an intact mill and an abandoned mill, illustrating how even a reasonably well-preserved ‘archaeological’ stamp mill is a very decayed item compared to a mill in operational condition. Usually only the more robust parts of the mill have survived for modern archaeological study. The lighter battery parts and the myriad of smaller items found inside industrial buildings rarely survive. The archaeological record is therefore skewed distinctly towards the heavy engineering aspects of battery technology. This and other biases are caused by a number of factors, some dating to the time of closure, and others that have occurred subsequently.

Figure 130. The interior of the restored Coromandel Government Battery (site T10/1115) in 2011.

Figure 131. The United Goldfields Battery (site F41/484) near Macetown in Otago in 2011.
Factors dating to closure include:

- Full or partial dismantling for removal and sale or reuse.
- Full or partial dismantling for scrap.
- Removal of the battery building.
- Deliberate sabotage.  

Factors post-dating closure include:

- Full or partial dismantling for removal and sale or reuse.
- Full or partial dismantling for scrap.
- Removal or collapse of the battery building.
- Decay/collapse of the stamp mill frame.
- Re-working of the mill site for spilled or trapped gold.
- Fire, flood or slip.
- ‘Preservation period’ restoration or rebuild.
- ‘Preservation period’ removal for display elsewhere.
- Re-opening of mining operations, leading to site disturbance or destruction.

Machinery in the goldfields was often highly mobile, as mining companies came and went and their machinery was erected, sold, dismantled, moved, possibly updated, and re-erected, sometimes several times over. As Ritchie (1990: 9) has observed, the surviving equipment at a site is often that associated with the latter stages of a company’s endeavours, and there is therefore an inherent ‘late bias’ associated with this material. Acting with a distorting effect is the fact that as very second-hand batteries travelled from site to site, they might already have been obsolete when erected in their last position, thereby leaving an archaeological record of early technology on a late site. In addition, obsolete equipment would have been abandoned more readily than up-to-date equipment.

Late bias is particularly relevant with regard to the very earliest stamp mills. There are no extant examples of the first Cornish Stamps that were used in the first quartz workings in the early 1860s, such as in the Upper Shotover where 2 sets of stamps totalling 12 heads were recorded working in 1864 (AJHR 1865 C4A: 17). Some very primitive stamp parts, including square section stems, are held at the private museum at Mitchell’s Gully Goldmine at Charleston on the West Coast, but these lack provenance to specific mill sites.

Once closed, a battery might have been abandoned intact, dismantled for removal and reuse, or dismantled for scrap. The latter two actions were sometimes immediate or could be delayed for many years. The scrapping of old batteries was particularly common in the post-Second World War period, and was not always done legally. The Bendigo Battery at Waiorongomai was taken for scrap in 1950 without the legal owner’s knowledge or permission, leading to a conviction for theft and sentence of 12 months hard labour for the perpetrator (Hart 2005). The lack of large surviving stamp mills is probably partly due to the fact that good access roads were required to build the larger mills, and therefore there was good access for the removal of the machinery after closure.

---

26 This entailed the owners disabling machinery that they were abandoning so that no-one else could walk in and reuse it at no cost.
Even if a battery was left intact, its slow decay was inevitable. Although battery structures were robust, they were often housed in relatively lightly-built timber-framed corrugated-iron buildings. Many such buildings were stripped of their iron during shortages after the two World Wars, and even the few that survived until recent decades have mostly succumbed. The Anderson’s Battery building at Macetown finally collapsed in the 1970s (Figure 132), while the Lillis Battery building in the Coromandel is in the process of collapsing as this is written (2013).

Once the protection afforded by a battery house was lost, the stamp mill itself was exposed to the weather. All of the surviving stamp mills that stand in the open have suffered from decay, which has been most rapid for smaller parts, and for mills that were built from less durable timbers (see Figure 133). Even structures that appear sound are often badly deteriorated, for example the Gallant Tipperary/Nugget Battery beside the Shotover River (see Figure 313 in Chapter 10) looks solid from a distance, but is suffering from severe pipe rot. A number of timber-framed mills have been rebuilt by the New Zealand Forest Service and the Department of Conservation, such as the Croesus, Kirwan’s Reward (Figure 133) and Serpentine Batteries. At many sites nothing is now left of the timber parts of the frame, and only the metal components survive.

---

Pipe rot occurs when the inner section of a timber decays, leaving only a thin shell of sound wood.
Iron-framed stamp mills are far more durable than timber-framed mills, and a number remain intact and in good condition (for example the main parts of Anderson’s Battery at M acetown and the Alpha Battery in Fiordland). However, they were often on timber foundations, and these are prone to decay. Recently the Department of Conservation has retimbered the foundations for the Golden Lead and Johnston’s United batteries. Iron-framed mills were also attractive sources of scrap iron. The Alpine Battery near Lyell was equipped with an iron-framed mill that was broken up for scrap after it closed, and small but identifiable fragments of its kingposts can be seen at the site today.

Recovery of lost gold from battery sites was commonly carried out after closure. This was carried out in two main ways; looking for gold trapped in the machinery, and looking for spilled gold in the surrounding ground. Possible evidence of the former is to be seen at the Ajax Battery in the Murray Creek goldfield near Reefton. The iron-framed 15 stamp battery is in place but has been smashed to the extent that it is likely that explosives were used to break it up. It was possible that this was done simply to break it up for scrap, but much of the ironwork has been left on site (Figure 134).

The ground around a stamp mill would often be ‘cleaned-up’ after the mill closed and was dismantled. After the Victoria Battery at Waikino closed in 1952 the residues from around the site were treated using a tube mill and Wilfley table (AJHR 1956 C2: 43; 1958 C2: 26). During the Depression of the 1930s unemployed men not only worked on subsidised schemes prospecting old mining fields (see Chapter 4 above), but many old battery sites were also dug over. Idriess (1936: 224-227) gave specific directions for fossicking old battery sites:

Perhaps you are carrying the swag, are broke, and nobody loves you. Off the road you see an old battery site. Nothing there now but a rusted boiler and the charred stumps of the shed, all overgrown by grass and looking as forlorn as you feel. Not at all. That ruin may be worth £100 to you… First, scratch around the forge site…if there is any stone or brick-work of the forge left, pull it apart…dig six inches deep under and all around where the forge was…find where the tables were, dig under and round for a depth of six inches…examine carefully the old mortar box; dig under it.

These instructions describe disturbance seen at some battery sites, such as Johnston’s United Battery. The ground around the front of this mill had been dug out, exposing most of the foundation timbers, and a tailrace runs through the middle of the site suggesting that some form of sluicing or water washing of the soil was undertaken.
There has been a distinct geographical influence on historic mining machinery survival. As mentioned above, scrap dealers have removed many batteries, and those batteries that were most easily accessible and closest to centres of population have generally suffered the worst. In the historically important and rich mining area around Thames, Ritchie (1990: 27) lamented that with the exception of the Sylvia Battery all of the other battery sites had been ‘virtually obliterated,’ and the Sylvia had been stripped of all its machinery with just some sections of cyanide tanks remaining. Conversely, Central Otago and the West Coast have good representative samples, while the extremely remote Alpha and Golden Site Batteries in Fiordland stand virtually complete.

Attitudes towards abandoned mining equipment have changed over time. When first abandoned, battery sites were seen simply as discarded industrial equipment, their value limited to their ability to be reused or scrapped. Gradually their historical values began to be appreciated, although periods when scrap prices were high saw many removed. In the 1970s particular efforts were made to protect goldfields heritage, with the Otago Goldfields Park being proposed in 1971 and opened in 1980 (Mason 1981). This multi-location park included a number of battery sites, including the Invincible Battery near Glenorchy and the Canton Battery at Waipori. It was in this period that the Forest Service began to retimber a number of stamp mills, including the Croesus Battery near Lyell and the Garden Gully Battery near Blackball. Restoration work has been continued by the Department of Conservation, particularly on the West Coast and more recently in Otago (Serpentine and Come-in-Time Batteries) and Nelson (Johnston’s United Battery). One battery, the Croesus, has even undergone its second restoration as the beech timbers used in the 1980s decayed rapidly.

While the heritage values of the sites that do survive are now widely recognised, many threats still exist. The Crystal Battery in Sawyer’s Gully, Skippers, was destroyed in the last decade by floods. The attention of scrap merchants is also still an issue, and part of a collection of battery equipment from the Coromandel area was stolen in 1994 from the Victoria Battery site at Waikino (Figure 135) (G. Mayclair, pers. comm. 2011; Ritchie 1990: 20).

**Figure 135. The Mayclair Collection of battery equipment laid out at the Victoria Battery site in the early 1980s (Waihi Leader postcard).**

Well-intentioned removal from site continues to threaten some batteries. Many stamp mills have been removed from their original sites (even if this was on public land) for re-erection outside museums. Field and Olssen (1976: 64, 66, 67) illustrated Bikerton’s Battery at Nenthorn and the Bonanza Huntington Mill nearby in their working locations, but both of these have since been moved. Bikerton’s Battery is now at Macraes Flat village while the Huntington Mill has been re-erected at the Golden Point Reserve. It is a moot point as to whether this type of action
preserves the battery or damages the site in question. In some cases, such as the White’s Reef Battery near Alexandra or the Iris Battery parts now at the Opitonui Battery site on the Coromandel Peninsula (Figure 136) the equipment has been removed and is yet to be restored or re-erected, and has an uncertain future.

Figure 136. The parts of the Iris Battery at the Opitonui Battery site in 2011.

Only four mill sites can still be regarded as fully intact (ie left largely as they were when last operated for their original purpose, inside a standing building), these being Callery’s Battery at Macraes Flat, the small Sawyer’s Battery in Thames, and the Lillis and Government Batteries on the Coromandel Peninsula, although the Government Battery had some parts removed and was subsequently restored, and the Lillis Battery is not a stamp mill but is actually a tube mill plus two Berdans. Callery’s and the Government Batteries are still run for display on occasion (the latter on a regular basis) while the Lillis Battery is presently (2013) collapsing and will not survive.

Site Survey Methodology

Site selection for this research was based heavily on the presence of surviving machinery, preferably with the main stamp mill still being on site (even if in pieces). Because of this focus on surviving machinery, relocated mill machinery in museums and on public display has also been of use.

As already mentioned, the New Zealand Archaeological Association Archsite database presently contains records for 170 stamper batteries (including some that were added as a result of this research), and this was the main tool used for site selection, combined with discussion with local historians and Department of Conservation staff. Many, but not all, stamp mill sites have been described in archaeological reports, although the level of detail in these varies greatly. Some sites had been personally previously visited and recorded in some detail, such as the Alpha and Golden Site Batteries in Fiordland (Petchey 2005b) and these were not revisited. Other sites were selected on their suitability based on existing records, and were then visited during 2010 to 2012. A few remote sites were not found, but in general most sites were relatively straightforward to relocate.
Field recording was non-intrusive, and the only excavation work undertaken was on behalf of the Department of Conservation during restoration work on Johnston’s United Battery, when the opportunity was taken to record the original foundation timbers prior to their replacement. Otherwise all sites were recorded using standard field survey methods. The map co-ordinates for each site were taken using a Garmin 12 hand-held GPS. A basic measured sketch map was made of most sites (if there was no existing map or plan), and the machinery was recorded. Measurements were taken in feet and inches (the units in which the machinery was designed and built), and vernier callipers were used to ensure accuracy when measuring camshafts and stamp stems. Finally, the sites were all thoroughly photographed.

Weight Calculations

Because two of the basic parameters for stamp mills were the numbers of stamps and the weight of the stamps, these details are important aspects of the archaeological data. As it is not possible to weigh a ½ ton stamp in the field, weight estimates had to be based on a volumetric calculation, using detailed field measurements of the stamp assemblies. This was carried out for a sample of 16 mills. In each case the volume (in cubic inches) of all the components was calculated and this figure was then multiplied by the standard weight of wrought iron (0.278 lb per cu. in.) as given in Clark (1897: 219). The weight of wrought iron was used as it lies between the weights of cast iron (0.26 lb) and steel (0.283 lb) given in the same source, and therefore provides an average value allowing for the use of different materials in different components.

Summary: The Representativeness of the Archaeological Record

From the above discussion it can be seen that a large number of factors have affected stamp mill survival, and thus the archaeological sample available for study. Although the overall number of stamp mill sites considered in this thesis is large enough to form a reliable sample, there are a number of distinct and identifiable biases in the archaeological record:

- A late bias, with the last period of operation of any site being the most visible.
- An early bias, where old machinery was moved to a new site.
- A bias towards smaller stamp mills (1 to 20 stamps, with most in the 5 to 10 stamp range).
- A bias towards remote/back country stamp mills.
- A bias towards the larger and more robust items of plant within any single site.

The first two of these biases run directly counter to each other, and can best be addressed through detailed historic research, to try to identify the origins of any machinery in use at a particular site. The last of the biases provides one particular problem with individual site interpretation. Del Mar (1912) identified five key factors that needed to be correlated when setting up and operating a stamp battery; weight of stamp, height of drop, number of drops per minute, character of screen and height of discharge (all of which are described in Chapter 5). Of these, only the weight of the stamp can be calculated for most battery sites (and this relies
on a volumetric calculation with a degree of error), as the other parameters were adjustable (and so only the very last setting can be determined) and/or relied on parts that rarely survive, such as the screens. This means that archaeological examination of the fine-scale operational ‘tuning’ of stamp mills is not possible in most cases. What information can be gleaned will have a late-bias, as the mills stand now as they were when run for the last time.
Chapter 8  
**The Archaeological Evidence: the Stamp Mill in Detail**

This chapter examines the New Zealand archaeological evidence for the individual component parts of the stamp mill. The structure of this chapter follows the same pattern and order as Chapter 5, allowing a direct comparison between the contemporary engineering and archaeological records.

**Group 1: The Frame**

The archaeological evidence for the stamp mill frame in New Zealand in many ways agrees well with the contemporary technical literature, but there are also significant variations, particularly in the upper framework. The use of two separate structures; the upper frame with its cribwork of foundations, and the mortar with its mortar block; is well represented amongst those mills with timber foundations. The few exceptions that use horizontal mortar beams combined with the foundation frame also agree with the contemporary literature regarding this type of construction. The use of concrete foundations in some later mills is also consistent with contemporary sources.

Surviving battery frames fall into a number of main material classes: below-ground foundation structures are of timber or concrete, while above-ground frames are of timber or iron.

**The Lower Framework**

*Timber Foundations: Mud Sills & Cross (or Streak) Sills*

This part of the battery structure is the most difficult to inspect and describe because it is usually buried. A number of sites could be inspected as their foundations have been fully or partially exposed, but the sample size is unavoidably small. However, based on observations that can be made it appears that the timber cribwork of mud and cross sills was the most common form of stamp mill foundation. Table 12 gives the recorded timber dimensions.

The Alpine Battery (site F42/265) has the most accessible original foundation structure in New Zealand, as it was dismantled for removal in about 1896, but was never moved and is still on site in pieces (Figure 137). The lower framework consists of a single layer of conventional timber mud and cross sills with the front mud sill placed lower than the rear sill due to the sloping site, and risers are used to level the structure. The cross sills in turn supported a timber A-frame upper structure (dismantled).
Figure 137. The Alpine Battery (site F42/265) foundations in 2011.

Table 12. Foundation timber dimensions

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Mud sills (inches)</th>
<th>Cross sills (inner) (inches)</th>
<th>Cross sills (outer) (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>12 x 10</td>
<td>12 x 10</td>
<td>12 x 10</td>
</tr>
<tr>
<td>Golden Lead</td>
<td>L31/29</td>
<td>12 x 12</td>
<td>12 x 15</td>
<td>12 x 15</td>
</tr>
<tr>
<td>Come in Time</td>
<td>G41/251</td>
<td>12 x 14</td>
<td>10 x 10</td>
<td>12 x 14</td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td>15 x 13</td>
<td>12 x 12</td>
<td>12 x 12</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>Buried</td>
<td>18 x 14</td>
<td>12 x 14</td>
</tr>
</tbody>
</table>

The Golden Lead (site L31/29) and the Kirwan’s Reward (site L30/62) batteries also have conventional crib structures, but in both cases they are doubled, with two layers of mud and cross sills, and extra mud sills are used in each layer (Figure 138). In these examples the mud sill and cross sill sizes are consistent within each structure.
The Come-in-Time (site G41/251) and Homeward Bound (site F41/477) batteries also have conventional foundations, but use different sizes of cross sills within each structure. The Come-in-Time has a smaller central cross sill than the outside sills, while the Homeward Bound has a much heavier central sill. In the latter case the use of the larger central sill would have been to support the very heavy central battery post that carried higher loads than the outside posts.

The occasional use of horizontal mortar beams (instead of vertical mortar blocks) was also observed in three sites; Johnston’s United (site M25/73), No. 2 South Larry’s (site L30/7), and the Culliford (site M28/4). At Johnston’s United the foundations of the left hand mill were completely exposed during restoration work in 2011 (Figures 139 & 140), and were very heavy in construction with five mud sills and five cross sills, all made from squared logs. The timber dimensions varied from approximately 18 inches square to 16 by 13 inches, with the top mortar block being 16 by 20 inches. The heaviest cross sills were placed beneath the battery posts. This arrangement agrees with the contemporary descriptions of this type of construction (eg Richards 1906: 148, Figs 95a,b, 96).
Figure 140. Plan and elevation (left) and isometric drawing (right) of the foundations of the left hand section of Johnston’s United stamp mill (site M25/73) (P. Petchey & S. Bagley).

The available evidence for most timber-foundation batteries is therefore of a reasonably standard foundation design, with one or more layers of mud and cross sills set out as cribwork, with extra layers, additional mud sills and very heavy timbers used as appropriate to accommodate for poor or sloping ground conditions, or heavy stamp mill weights. The evidence agrees well in terms of both structure type and timber size with the contemporary engineering sources discussed in Chapter 5 above.

Concrete Foundations

Archaeological evidence for the use of concrete foundations is also ample, although none have been fully excavated to determine their depth or overall bulk. The use of concrete can be divided into two broad categories: the use of concrete just for the mortar blocks and the use of full concrete foundations for the entire mill. While in Chapter 5 above it was simple to separate the two and discuss them individually, this is not so simple in the archaeological record in the absence of any archaeological excavation. Because of this, both complete concrete foundations and concrete mortar blocks are discussed together here. Table 13 gives the details of these mill sites, based on surface observations alone.

The progression from partial to full concrete foundations is illustrated in Figures 141 and 142. The United Goldfields Battery at Macetown (Figure 141) (site F41/484) has a conventional timber frame and foundations, but has concrete mortar blocks. By contrast, the Stoneburn battery near Macraes (Figure 142) (site I43/75) has concrete foundations for the entire mill.
Table 13. Stamp mill sites with concrete foundations.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Type</th>
<th>Date of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td>Mortar &amp; frame</td>
<td>1910</td>
</tr>
<tr>
<td>Bickerton’s</td>
<td>I43/136</td>
<td>Mortar &amp; frame</td>
<td>ca1914</td>
</tr>
<tr>
<td>Buckland’s</td>
<td>I43/99</td>
<td>Mortar (collar)</td>
<td>ca1917</td>
</tr>
<tr>
<td>Callery’s</td>
<td>I42/161</td>
<td>Mortar</td>
<td>After 1902</td>
</tr>
<tr>
<td>Cherry &amp; Son</td>
<td>T13/294</td>
<td>Mortar (collar)</td>
<td>1932</td>
</tr>
<tr>
<td>Deep Dell</td>
<td>I42/15</td>
<td>Mortar &amp; frame</td>
<td>1912</td>
</tr>
<tr>
<td>Golden Bar</td>
<td>I43/88</td>
<td>Mortar &amp; frame</td>
<td>1927</td>
</tr>
<tr>
<td>Govt., Coromandel</td>
<td>T10/1115</td>
<td>Mortar &amp; frame</td>
<td>1899</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>Mortar</td>
<td>1910</td>
</tr>
<tr>
<td>Morning Star</td>
<td>B46/49</td>
<td>Mortar (&amp; frame?)</td>
<td>1895</td>
</tr>
<tr>
<td>Rise &amp; Shine</td>
<td>G41/277</td>
<td>Mortar &amp; frame</td>
<td>1939</td>
</tr>
<tr>
<td>Snowy River</td>
<td>L31/37</td>
<td>Mortar &amp; frame</td>
<td>1936</td>
</tr>
<tr>
<td>Stoneburn</td>
<td>I43/75</td>
<td>Mortar &amp; frame</td>
<td>ca1913</td>
</tr>
<tr>
<td>United Goldfields</td>
<td>F41/484</td>
<td>Mortar</td>
<td>ca. 1910-1918</td>
</tr>
<tr>
<td>Victoria</td>
<td>T13/300</td>
<td>Mortar</td>
<td>1896-1900</td>
</tr>
</tbody>
</table>

Figure 141. The United Goldfields Battery (site F41/484) at Macetown in 2011.

Figure 142. The concrete foundations for the Stoneburn Battery (site I43/75) in East Otago.
The historical sources discussed in Chapter 5 suggest that the use of concrete for stamp mill foundations became common after the turn of the twentieth century, and this is supported by the archaeological evidence (Table 13). There are also several good examples of change over time whereby batteries were initially built using timber foundations, while later modifications and additions utilised concrete. These include the Victoria Battery at Waikino (site T13/300) and the Snowy River Battery at Waiuta (site L31/37).

The Victoria Battery at Waikino was erected between 1896 and 1906 by the Waihi Gold-Mining Company, and remained in service until 1955-1956. The surviving stamper foundations (Figure 143) show that timber was used for the initial construction, and concrete was used for subsequent additions and repairs.

Figure 143. The surviving foundations of the Victoria Battery stamp mill (site T13/300) in 2011.

At the Snowy River Battery at Waiuta (site L31/37), the timber mortar blocks of the original 1908 mill sit beside the concrete mortar block and mill foundation of the 1936 addition (Figure 144) (Hancox 1985: 17-20).

Figure 144. Timber and concrete mortar blocks at the Snowy River Battery (site L31/37) in 2011.

There is therefore good archaeological evidence that concrete construction became commonly used from about 1900, although it was by no means universally adopted, and many post-1900 examples of timber foundations exist (for example, the Cosmopolitan, site H44/745, erected in 1917).
The Upper Framework

The archaeological evidence of upper framework on stamp mills can be divided into two material classes: timber and iron. As discussed in Chapter 5, the contemporary literature suggested that there was a variety in the layout and form of stamp mill frames, and this is borne out by the New Zealand archaeological evidence. However, this evidence also indicates that while some New Zealand mills were absolutely typical of international trends in their period, others varied from the contemporary engineering descriptions.

This has created a difficulty in the use of terminology to describe the frame forms. The intention of this research is to consistently use the correct contemporary terminology for all aspects of stamp mill design and engineering, but it has been found necessary to adapt some of the old terminology and develop some new terminology to accommodate the archaeological evidence. In particular this applies to the timber ‘A-frame’ and ‘trestle-frame’ stamp mills described below.

Timber Frames

During the archaeological survey, 31 timber frames could be confidently identified in situ, and a further 6 in mills that have been moved for modern display or recreation. There is a definite late-bias in these frames because of the effect of decay, meaning that in general only more recent frames have survived, although timber species and environmental conditions are also important factors. No two of the surviving frames are identical, but some general categories of frame form can be identified based on the archaeological evidence:

- A-frame (diagonal legs, no vertical post).
- Vertical battery post, diagonal timber braces (also referred to as an ‘A’ frame in some contemporary sources).
- Vertical battery post, diagonal iron braces.
- Vertical battery post, knee-frame.
- Vertical battery post, trestle-frame.

A-Frame Mills

As outlined in Chapter 5, the contemporary literature generally identified A-frame mills as having vertical battery posts supported by angled timber braces fore and/or aft, with only brief mention of the use of pairs of inclined battery posts and no vertical post (Del Mar (1912: Figure 25). However the New Zealand archaeological record has very clear evidence of the widespread use of both forms. In the discussion here these two different patterns have been separated, with the ‘true’ A-frame considered first, followed by the various forms of mill frame with vertical battery posts, including the ‘braced vertical post frame.’

The difference between the two forms is important, as each type bore load in a different way. In the true A-frame structure each pair of battery posts was mounted on a cross sill, and was bolted together at the apex. This created a rigid triangular form that needed no further bracing fore or aft. The camshaft load was carried on a large beam bolted across the ‘A.’ Conversely, the ‘vertical post A-frame’ carried the camshaft load on the vertical battery post. Twelve
examples of true A-frame stamp mills were recorded during the site survey (Table 14). Figures 145 to 147 illustrate two typical examples, the Golden Site in Fiordland (site B46/88) and the United Goldfields at Macetown (site F41/484).

Figure 145. The Golden Site stamp mill (site B46/88) in Fiordland.

Figure 146. Elevations of the Golden Site stamp mill.

An additional A-frame battery is on display, and is operational, at the Kawarau Gorge Mining Centre in Otago. This was removed from the scheelite battery near Glenorchy.
Figure 147. An end view of the A-frame of the United Goldfields Battery (site F41/484) at Macetown in 2011.

Table 14. A-frame stamp mills recorded during the archaeological survey. Date (a) is the date of manufacture of the main components, Date (b) is the date of erection at the present site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Stamps</th>
<th>Comments</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Nations</td>
<td>F41/483</td>
<td>5</td>
<td>Part buried</td>
<td>ca1877</td>
<td>1877</td>
</tr>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>10</td>
<td>Disassembled</td>
<td>pre1882</td>
<td>1882</td>
</tr>
<tr>
<td>Smith’s Gully</td>
<td>F42/101</td>
<td>2</td>
<td>Disassembled, parts missing</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>H44/745</td>
<td>5</td>
<td>Truncated form</td>
<td>1876</td>
<td>1917</td>
</tr>
<tr>
<td>Croesus</td>
<td>L29/2</td>
<td>10</td>
<td>Retimbered</td>
<td>1883</td>
<td>1883</td>
</tr>
<tr>
<td>Crown</td>
<td>B45/58</td>
<td>5</td>
<td>Fragmentary</td>
<td>pre1889</td>
<td>1907</td>
</tr>
<tr>
<td>Fraser’s Gully</td>
<td>I44/517</td>
<td>3</td>
<td>Very light, Disassembled</td>
<td>?</td>
<td>1930s?</td>
</tr>
<tr>
<td>Golden Site</td>
<td>B46/88</td>
<td>10</td>
<td>Intact</td>
<td>pre1894</td>
<td>1894</td>
</tr>
<tr>
<td>Premier</td>
<td>F41/471</td>
<td>5 (of 30)</td>
<td>Part of mixture of frames</td>
<td>?</td>
<td>1878-1898</td>
</tr>
<tr>
<td>Serpentine</td>
<td>H42/2</td>
<td>10</td>
<td>Retimbered</td>
<td>1878*</td>
<td>1890</td>
</tr>
<tr>
<td>United Goldfields</td>
<td>F41/484</td>
<td>10</td>
<td>Intact, poor condition</td>
<td>1898*</td>
<td>Pre-1916</td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/25</td>
<td>5</td>
<td>Intact</td>
<td>1871</td>
<td>ca.1896</td>
</tr>
</tbody>
</table>

*In both cases the date of one mortar box is known and one is unrecorded.

Most surviving A-frame mills are of the same general pattern (with two notable exceptions discussed below). The A frame legs are typically between 9 ½ inches square (Young Australian Battery) to 12 by 10 inches (Golden Site Battery), while the cam beams are typically within an inch of 20 inches deep and 8 inches wide (Table 15).
Table 15. Timber sizes in intact original A-frame batteries.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>A frame leg dimensions (inches)</th>
<th>Cam beam dimensions (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>12 x 10</td>
<td>20 x 8</td>
</tr>
<tr>
<td>Fraser’s Gully</td>
<td>I44/517</td>
<td>6 ½ x 3</td>
<td>4 ½ in deep</td>
</tr>
<tr>
<td>Golden Site</td>
<td>B46/88</td>
<td>12 x 10</td>
<td>19 7/8 x 8</td>
</tr>
<tr>
<td>Premier</td>
<td>F41/471</td>
<td>11 ¼ x 8 ¾</td>
<td>18 x 7 1/2</td>
</tr>
<tr>
<td>United Goldfields</td>
<td>F41/484</td>
<td>11 ½ x 9 ½ to 12 x 8 ½</td>
<td>20 x 8</td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/25</td>
<td>9 ½ x 9 ½</td>
<td>17 x 10</td>
</tr>
</tbody>
</table>

The surviving examples that do not fit this general pattern are the Cosmopolitan Battery and the Fraser’s Gully Battery. The Cosmopolitan Battery (site H44/745) is not quite a true A-frame, but rather is a truncated form, with the apex cut off and a short beam used to join the converging top ends of the battery posts. It does have lightweight vertical battery posts, but the camshaft loads are carried by a camshaft beam mounted across the main legs in the same fashion as the A-frame.

The small Fraser’s Gully stamp mill (site I44/517) (Figures 148 & 149) has the basic (true) A-frame form, but is a much lighter structure, and was probably designed as a portable prospectors’ battery.

*Figure 148. The collapsed Fraser’s Gully stamp mill (site I44/517) in 2010.*

*Figure 149. Reconstruction of the Fraser’s Gully stamp mill.*

The ‘true’ A-frame stamp mills therefore make a coherent group, with generally little variation in design and dimensions within that group, other than the two quite distinct outliers (the Cosmopolitan and Fraser’s Gully). This consistency can be observed over a large
geographical area (Fiordland in the south to Buller in the north), although the identified examples are confined to the South Island. The mills are also all relatively lightweight, the calculated stamp weights of two, the Young Australian and the Alpine being 565 lb and 685 lb respectively. Where the date of manufacture of a mill is known, it is generally early, and a number certainly date to the 1870s. The early date and lightweight nature of the design probably explains why it was not widely discussed in the engineering literature with its bias towards late and heavy mills.

**Vertical Battery Posts/Kingposts**

All other stamp mill timber frames that were recorded during the archaeological survey utilised vertical battery posts. There was a wide variation in designs, including timber and iron braced battery posts, knee-frames with load-bearing battery posts, trestle frames that had load-bearing cam beams and lightweight battery posts, and a small number of multiple-post mills. As discussed in Chapter 5, the direction of the drive to the camshaft was an important factor in the placement of the bracing for the mill frame.

**Braced Vertical Post Frame**

**Vertical Battery Post, Timber Braces**

This form of stamp mill structure, using a vertical load-bearing battery post with diagonal timber braces, is the type that was often described as an A-frame in the contemporary literature (Chapter 5). However, for the reasons already discussed, this archaeological discussion considers them as a sub-set of vertical frame mills rather than A-frame mills. Eight examples were recorded during the survey (Table 16), and can be divided into rear brace, front brace and double (front and rear) brace. It is common for the longest brace in these mills to also have a parallel iron tensioning rod, to hold the structure tightly together.

**Table 16. Stamp mills with vertical battery posts and timber braces.**

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Stamps</th>
<th>Braces</th>
<th>Comments</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callery’s</td>
<td>I42/161</td>
<td>5</td>
<td>Forward</td>
<td>Operational</td>
<td>?</td>
<td>After 1902</td>
</tr>
<tr>
<td>Garden Gully</td>
<td>K31/51</td>
<td>10</td>
<td>Double</td>
<td>Retimbered</td>
<td>ca1881</td>
<td>1905</td>
</tr>
<tr>
<td>Government, Coromandel</td>
<td>T10/1115</td>
<td>6</td>
<td>Forward</td>
<td>Operational</td>
<td>ca1899</td>
<td>1900</td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td>15</td>
<td>Double</td>
<td>Restored</td>
<td>ca1900, 1902</td>
<td>1900, 1902</td>
</tr>
<tr>
<td>McNichol’s</td>
<td>E40/34</td>
<td>3</td>
<td>Forward</td>
<td>Part buried</td>
<td>1892</td>
<td>1948</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>10</td>
<td>Forward</td>
<td>Intact</td>
<td>ca1903</td>
<td>1903</td>
</tr>
<tr>
<td>Rise &amp; Shine</td>
<td>G41/277</td>
<td>5</td>
<td>?</td>
<td>Dismantled, off site</td>
<td>?</td>
<td>1939</td>
</tr>
<tr>
<td>Sawyer’s</td>
<td>T12/1411</td>
<td>1</td>
<td>Forward</td>
<td>Complete</td>
<td>?</td>
<td>1930s</td>
</tr>
</tbody>
</table>

Figure 150 shows a typical example of the braced vertical post mill frame, the Kirwan’s Reward (Lord Brassey) Battery near Reefton (site L30/62). This mill has recently (2010) been
retimbered by the Department of Conservation, but details of its original construction were taken before and during the restoration (Petchey 1998a; J. Staton pers. comm.). It is a double brace mill, with the longer front braces placed to resist the pull from the Pelton wheel drive that was placed in front of the machine.

Figure 150. Kirwan’s Reward battery (site L30/62) (Petchey 1998a; J. Staton pers. comm. 2013).

The Nugget Battery (Figure 151) (site F41/23) beside the Shotover River in Otago is another typical example of a front-braced mill that was powered by a Pelton wheel. In this example the Pelton wheel is behind the mill, but probably drove via a layshaft in front, hence the need for front bracing. The Nugget also possibly had ore bins to the rear that were at least in part supported by the battery frame, increasing the need for front bracing.

Figure 151. The Nugget Battery (site F41/23) in 2011.

An exception to the rule regarding power supply and brace placement is the small 3 stamp McNichol’s Battery (site E40/34) in the Mt Aurum Basin (Figure 152). This mill also has a hybrid design that had a cam beam like a trestle-frame (see below) but still had a load-bearing vertical battery post and diagonal front braces
mounted off the post. Its differences can be at least in part explained by it being essentially a small prospector’s mill that had been moved at least once in its life, with no evidence of how the drive was arranged when it was originally built.

![Figure 152. (Right) McNichol’s Battery (site E40/34), probably in the 1990s (Department of Conservation).](Image)

The timber dimensions in the surviving braced vertical post mills are shown in Table 17. With the exception of the lightweight McNichol’s, the battery post sizes are generally large as they have to take the vertical camshaft load. There is a correlation between battery post size and stamp weight, which range from the heavy stamps (the 1030 lb stamp Coromandel Government Battery) down to lightweight stamps (the ca. 560 lb stamp McNichol’s Battery).

![Table 17. Timber dimensions in braced vertical post stamp mills](Table)

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Battery post (inches)</th>
<th>Front brace (inches)</th>
<th>Rear brace (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callery’s</td>
<td>I42/161</td>
<td>18 ¾ x 9 ½</td>
<td>9 ¾ x 9 ¾</td>
<td>-</td>
</tr>
<tr>
<td>Govt. Coromandel</td>
<td>T10/1115</td>
<td>16 x 15</td>
<td>10 x 10</td>
<td>-</td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td>24 x 10 ½</td>
<td>12 x 12</td>
<td>12 x 12</td>
</tr>
<tr>
<td>McNichol’s</td>
<td>E40/34</td>
<td>18 x 9 ½</td>
<td>9 ½ x 9 ½</td>
<td>-</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>18 x 9 ½</td>
<td>9 ½ x 9 ½</td>
<td>-</td>
</tr>
</tbody>
</table>

The braced vertical post mills form a coherent class throughout New Zealand, with examples found from Otago to the Coromandel. As can be seen from Table 17, all of the surviving examples of this type of frame are of relatively late construction, typically 1900 or later. It therefore appears to have been a standard frame type of the later goldfields period.

**Vertical Battery Post, Iron Braces**

This form of mill is very similar in layout and structural form to the vertical battery post mill with timber braces, with the exception that as iron rods work best in tension, they need to be placed on the other side from a timber brace (that works in compression) to resist the same force. In practice, the available archaeological evidence is that iron rod braces were always used fore and aft (ie double braced). However, some care is required, as what might appear to

---

29 Government Battery stamp weight is calculated, the McNichol stamp weight is based on contemporaneous reports.
be an iron rod braced mill might be a timber braced mill with iron tensioning rods, but with the timber braces decayed away. This consideration discounted several sites from this discussion.

The archaeological sample for this type of mill is both small and fragmentary (Table 18). Three candidates were identified, but all were incomplete (the Culliford was very decayed prior to restoration).

Table 18. Stamp mills with vertical battery posts and iron braces.
Date (a) is the date of manufacture of the main components, Date (b) is the date of erection at the present site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Stamps</th>
<th>Braces</th>
<th>Comments</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>L31/27</td>
<td>5</td>
<td>Double</td>
<td>Very decayed</td>
<td>ca1890?</td>
<td></td>
</tr>
<tr>
<td>Culliford</td>
<td>M28/4</td>
<td>4</td>
<td>Double</td>
<td>Restored</td>
<td>ca1870</td>
<td>1870</td>
</tr>
<tr>
<td>Heart of Oak</td>
<td>F42/95</td>
<td>10</td>
<td>Double</td>
<td>Incomplete</td>
<td>ca1871</td>
<td>1871</td>
</tr>
</tbody>
</table>

The best evidence for this frame type are the A1 (Reefton) and Heart of Oak (Carrick Range, Otago) Batteries. Both are incomplete, but both have remaining timber battery posts (partial in the case of the A1) with iron rod braces attached. The A1 rods are connected to the top of the battery post using a forged iron saddle (Figure 153), while the heart of Oak rods are connected at different points fore and aft by bolts passing through the posts. The sample size of this frame form is too small to draw many conclusions, other to suggest that it was used from the early decades of the New Zealand goldfields for light to medium weight mills.

Figure 153. The remains of the A1 battery (site L31/27) in about 1975 (J. Staton, Department of Conservation).

**Vertical Battery Post, Knee Frame**

The knee frame uses a vertical battery post with a heavy horizontal beam connected either to the front of the post (front knee frame) or the rear of the post (rear knee frame), and thence to another supporting structure. As described in Chapter 5 above, by the beginning of the twentieth century the knee frame was regarded as the main form of battery by contemporary engineering authors. The knee frame mill has a number of similarities with what are termed here as ‘trestle frame’ mills (discussed below), particularly in the use of horizontal beams.
attached to the battery posts, but it is argued that they are different enough to be two distinct classes.

It is in the knee-frame mill that the biases of the archaeological record towards smaller and back-country machines (as discussed in Chapter 7) become apparent, as only one surviving example of a knee-frame battery was recorded; the Homeward Bound (site F41/477) at Macetown. However, the photographic evidence of the interiors of some of New Zealand’s largest stamp mills such as the Snowy River, Crown, Victoria and Grand Junction Batteries (Figure 154, and see also Nathan 2010: 62; McAra 1988: following pages 128, 240) suggests that this pattern of stamper frame was widely adopted in this class of mill. Callery’s Battery (site I42/161) has heavy knee beams, but these carry the ore feed floor, and it is not structurally a knee-frame mill.

Figure 154. The Grand Junction battery at Waihi under construction, showing the knee-frame structure (Sir George Grey Special Collections, Auckland Libraries, AWNS-19050914-10-3).

The Homeward Bound is a textbook example of its type. It is a 10 stamp back-knee (or reverse-knee) frame battery with built-in ore bins (Figures 156 and 157). It was built in 1899 by the Sandycroft Foundry Company of Chester, England for the OPQ Company at Waipori, and in 1910 was moved to become the Homeward Bound at Macetown, and was abandoned intact there.
Figure 155. A ten stamp back-knee frame stamp mill as built by the Sandycroft Foundry Company Limited of Chester, England (Louis 1902: 238).

Figure 156. The Homeward Bound Battery (site F41/477) in 2011.

The Homeward Bound stamp mill structure is heavily built, using large dimension timbers (Table 19). The battery posts are made from two timbers mounted face to face, in the fashion described by Richards (1906: 153). The stamps were a reported 1250 lb each (calculated weight = 1120 lb), placing it firmly in the heavyweight category, amongst the heaviest stamps to have been used in New Zealand. The drive to the camshafts was by belt from a lineshaft mounted on the cross sills just behind the battery posts, but the stresses from this source were probably negligible when compared to those from the ore bins. The Homeward Bound matches almost exactly the illustration of a Sandycroft Foundry 10 stamp mill published in Louis (1902: 238) (Figures 155 and 156), and is very close to the back knee frame illustrated by Truscott (1923) (Figure 157). This confirms that it was an example of contemporary international practice, and was up-to-date when it was in use in New Zealand.
Figure 157. Elevation of a back-knee frame battery (Truscott 1923) and side view of the Homeward Bound Battery in 2011.

Table 19. Dimensions of the main structural elements in the Homeward Bound Battery.

<table>
<thead>
<tr>
<th>Element</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH &amp; RH battery posts</td>
<td>24 in x 12 in</td>
</tr>
<tr>
<td>Centre battery post</td>
<td>24 in x 18 in</td>
</tr>
<tr>
<td>Stamp guide beams</td>
<td>14 ½ in by 8 ½ in</td>
</tr>
<tr>
<td>Centre knee beam</td>
<td>12 in x 12 in</td>
</tr>
<tr>
<td>Upper bin brace</td>
<td>11 ¾ in x 9 ½ in</td>
</tr>
<tr>
<td>Front bin posts</td>
<td>12 in x 12 in</td>
</tr>
<tr>
<td>Back bin posts</td>
<td>11 ½ in x 11 ½ in</td>
</tr>
</tbody>
</table>

**Vertical Battery Post, Trestle Frame**

The vertical post trestle frame mill is a class defined here based on the archaeological evidence, but is absent from most contemporary literature, although illustrations of this frame type do occur (see Figure 14 in Chapter 3). The frame form consists of a vertical battery post that is attached to a horizontal beam that is in turn supported at each end by vertical or inclined legs. This form of support is termed a ‘trestle’ (‘a support for something, consisting of a short horizontal beam or bar with diverging legs’ *Oxford English Dictionary*). The camshaft bearings are carried on the beam. In many ways this form is similar to the knee-frame, but the use of the load-bearing camshaft beam is used as a distinguishing feature.

Figures 158 and 159 illustrate a typical vertical post trestle frame mill, the Canton Battery at Waipori (site H44/831), built in about 1910. This is a 5 stamp mill that was constructed using a 10 stamp camshaft and frame, possibly with the intention of adding the extra 5 stamps at a later date (which never happened).
Ten examples of vertical post trestle frame mills were recorded during the archaeological survey (Table 20). All of these are missing elements, ranging from a few absent timbers to the entire frame being rotten. One example, the Crystal Battery (site E41/91) has been destroyed by floods since it was recorded in 1993 (Figure 160). A range of sizes of mill is represented in the archaeological sample, from the small 4 stamp Crystal Battery (site E41/91) to the remains of the 25 stamp Union Battery (site L30/65) near Reefton (Figure 161). One of the best surviving examples is the Come in Time battery near Bendigo (Figure 162). In most cases the battery post, trestle legs and camshaft beam were all large timbers (Table 21), but it is notable that the battery posts are generally smaller than those used in the braced vertical post mills (Table 17 above).
Table 20. Stamp mills with vertical battery posts and trestle frames. Date (a) is the date of manufacture of the main components, Date (b) is the date of erection at the last working site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Stamps</th>
<th>Comments</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canton</td>
<td>H44/831</td>
<td>5</td>
<td>Intact</td>
<td>?</td>
<td>ca1910</td>
</tr>
<tr>
<td>Come in Time</td>
<td>G41/251</td>
<td>10</td>
<td>Restored</td>
<td>1860s-1870s</td>
<td>1908</td>
</tr>
<tr>
<td>Crystal</td>
<td>E41/91</td>
<td>4</td>
<td>Destroyed</td>
<td>?</td>
<td>1936</td>
</tr>
<tr>
<td>Currie's</td>
<td>E40/24</td>
<td>5</td>
<td>Very decayed</td>
<td>?</td>
<td>ca1942</td>
</tr>
<tr>
<td>Invincible</td>
<td>E40/58</td>
<td>10</td>
<td>Very decayed</td>
<td>ca1882</td>
<td>1882</td>
</tr>
<tr>
<td>Leviathan</td>
<td>E41/89</td>
<td>4</td>
<td>Incomplete</td>
<td>ca1896</td>
<td>1896</td>
</tr>
<tr>
<td>Premier/Maryborough*</td>
<td>F41/471</td>
<td>5 (of 30)</td>
<td>Incomplete. Also has iron stays</td>
<td>?</td>
<td>1878-1898</td>
</tr>
<tr>
<td>Printz</td>
<td>D46/150</td>
<td>6</td>
<td>Timber decayed</td>
<td>1860s or 1870s</td>
<td>1880</td>
</tr>
<tr>
<td>Union</td>
<td>L30/65</td>
<td>25</td>
<td>Incomplete</td>
<td>1878,1887</td>
<td>1878-1886</td>
</tr>
<tr>
<td>Burnt Creek</td>
<td>H45/39</td>
<td>10</td>
<td>Display, all new timbers (incomplete)</td>
<td>?</td>
<td>1889</td>
</tr>
</tbody>
</table>

*The Premier Battery had a variety of frames in a row. See also A-frame mills above.

Table 21. Dimensions of main timber elements from vertical post trestle frame mills.

<table>
<thead>
<tr>
<th>Site</th>
<th>Battery post (inches)</th>
<th>Trestle legs (inches)</th>
<th>Cam beam (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canton</td>
<td>8 x 3 ¾</td>
<td>12 x 9 ¾</td>
<td>12 x 9 ¾</td>
</tr>
<tr>
<td>Come in Time</td>
<td>16 x 5</td>
<td>12 x 12</td>
<td>12 x 12</td>
</tr>
<tr>
<td>Crystal</td>
<td>16 x 6</td>
<td>12 x 6</td>
<td>12 x 6</td>
</tr>
<tr>
<td>Curries</td>
<td>12 x 8</td>
<td>Rotten</td>
<td>Rotten</td>
</tr>
<tr>
<td>Leviathan</td>
<td>16 x 5 ½</td>
<td>12 x 5 ¼</td>
<td>12 x 6</td>
</tr>
</tbody>
</table>

Figure 160. The Crystal Battery (site E41/91) at Skippers in 1993.

Figure 161. One of two remaining battery frames at the Union Battery (site L30/65), Globe Hill, Reefton, in 1994.
Figure 162. The Come in Time Battery (site G41/251) in 1995.

The vertical post trestle frame mill appears to have been built over a long period of time, from the 1870s through to the 1940s, over a large part of the country, and for a variety of sizes of mill. Printz’s Battery in Southland (site D46/150) has no timbers remaining, but is known from an early photograph to have had a trestle frame (Hall-Jones 1982), and was bought second hand from the Coromandel in 1880 (AJHR 1880 H26: 31). If it was built in the 1860s (as is possible, see Appendix A for a discussion on this point), and if it had the same frame arrangement in the Coromandel, it would indicate that the trestle frame was used throughout the country through the history of the goldfields.

The similarity of some of the trestle frames with the knee frame is clear (especially the Union Battery), with both using horizontal beams in connection with the battery post, but the archaeological evidence suggests that the two forms are distinct. The trestle frame found far greater favour in the ‘middle range’ of mills that are reasonably-well represented in the archaeological record, while the knee-frame appears to have been more popular in the larger mills that have not survived.

Vertical Battery Post, Mounted on Mortar Box

The use of timber battery posts that were bolted directly to the sides of the mortar box was recorded in a number of small semi-portable mills, and can be divided into two main groups; single post frames (Table 22); and double post frames (Table 23). Some iron-framed mills also had mortar box mounted posts, and are discussed below.

Single Post Frames

Three examples of small mills that used a timber post mounted on either side of the mortar box were recorded (Table 2), but all have been removed from their last place of work, are presently disassembled, and lack their battery posts. They can be identified by the cast recesses on either side of the mortar box. The Arethusa machine (from site D46/161), has these recesses together with a very broad base to increase the machines stability (Figure 163).
Table 22. Mortar boxes with mounts for bolt-on battery posts. 
Date (a) is the date of manufacture of the main components, Date (b) is the date of erection at the last working site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Stamps</th>
<th>Maker</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>2</td>
<td>Wilson, Otago Foundry</td>
<td>1887</td>
<td>1887</td>
</tr>
<tr>
<td>Iris</td>
<td>T11/625</td>
<td>3</td>
<td>Unprovenanced</td>
<td>?</td>
<td>1926</td>
</tr>
<tr>
<td>Thames School of Mines colln.</td>
<td></td>
<td>3</td>
<td>“The Riverside Battery”</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Figure 163. The mortar box from the Arethusa Battery (site D46/161).

Double-Post Frames

The double post frame used pairs of timber battery posts, with short beams between them (see Figure 47 in Chapter 5) in effect creating a 4-post layout, with a post at each corner of the machine (Figure 164). This arrangement is associated with a particular pattern of American triple discharge mortar box, the 4 battery posts being arranged around the screen openings. Four examples were recorded during the archaeological survey (Table 23), two in situ and two in off-site collections.

Table 23. Double-post frame stamp mills. 
Date (a) is the date of manufacture of the main components, Date (b) is the date of erection at the last working site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Stamps</th>
<th>Type</th>
<th>Maker</th>
<th>Comments</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>2</td>
<td>4 post</td>
<td>Joshua Hendy Machine Works, SF California</td>
<td>Very decayed</td>
<td>1906</td>
<td>1906</td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>2</td>
<td>4 post</td>
<td>Hendy</td>
<td>Timbers gone</td>
<td>1902?</td>
<td>1902</td>
</tr>
<tr>
<td>Govt Battery</td>
<td>T10/1115</td>
<td>2</td>
<td>4 post</td>
<td>Union Iron Works, SF California</td>
<td>Mortar box only, unprovenanced</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Mayclair Collection</td>
<td></td>
<td>2</td>
<td>4 post</td>
<td>Joshua Hendy Machine works, SF California</td>
<td>Mortar box only, unprovenanced</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
The 2-stamp Eureka Battery in Jennings Creek, Skippers, Otago (site E41/51) was still largely intact in the 1960s (Figure 164) and although the battery posts have now largely decayed away (Figure 165), some fragments remain for examination. It had a 7 ½ inch square post at each corner, and although only a 2 stamp mill it had reasonably heavy 780 lb stamps. The two machines with known histories, the Red Queen and Eureka, were erected in 1902 and 1906 respectively, and therefore this form appears to be a direct and late American influence. These machines are discussed further below under Mortar Boxes.

**Figure 164.** (Left) The Eureka Battery, probably in the 1960s (Lakes District Museum EL2679).

**Figure 165.** (Right) The Eureka Battery (site E41/51) in 2010.

### Iron Frames

Iron frame mills typically used cast iron battery posts and wrought iron braces, but were often mounted on timber foundations. Because of their durable materials, iron battery frames have tended to survive well, although this has been countered somewhat by their scrap metal value. Table 24 lists 19 iron frame mills, of which 13 are on site (in various states of repair), 1 is represented by fragments only, 4 are erected as static displays in public places, and 1 is in the Mayclaire Collection machinery at the Victoria Battery site. The geographical spread of these mills is from Fiordland to the Coromandel, indicating that they were widely adopted. Four distinct groups of iron frame mill were identified, (Type 1 to 4), based on the design of the battery posts.
Table 24. Stamp mills with iron frames.  
Date (a) is the date of manufacture of the main components (when known), Date (b) is the date of erection at the last working site. For a definition of the Types see the discussion below.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Stamps</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Comments</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajax</td>
<td>L30/31</td>
<td>15</td>
<td>Union Foundry, Ballarat</td>
<td>1</td>
<td>Smashed</td>
<td>1871</td>
<td>1871</td>
</tr>
<tr>
<td>Albion</td>
<td>Q27/112</td>
<td>10</td>
<td>Langlands, Melbourne</td>
<td>1A</td>
<td>Disassembled</td>
<td>1870s</td>
<td>1883</td>
</tr>
<tr>
<td>Alpha</td>
<td>B46/42</td>
<td>10</td>
<td>A&amp;G Price?</td>
<td>1</td>
<td>Intact</td>
<td>1899</td>
<td></td>
</tr>
<tr>
<td>Alpine</td>
<td>L29/3</td>
<td></td>
<td></td>
<td>?</td>
<td>Fragmentary</td>
<td>1871</td>
<td></td>
</tr>
<tr>
<td>Anderson’s</td>
<td>F41/473</td>
<td>10</td>
<td>R. Sparrow &amp; Co.</td>
<td>1</td>
<td>Intact</td>
<td>ca1907</td>
<td></td>
</tr>
<tr>
<td>Battery Creek</td>
<td>T12/1410</td>
<td>5</td>
<td>Pacific Iron Works, SF.</td>
<td>4</td>
<td>Partly intact</td>
<td>1889</td>
<td>1899?</td>
</tr>
<tr>
<td>Big River</td>
<td>L31/4</td>
<td>10</td>
<td></td>
<td></td>
<td>Part demolished</td>
<td>1870s?</td>
<td>1887-1914</td>
</tr>
<tr>
<td>Britannia</td>
<td>L29/15</td>
<td>5</td>
<td></td>
<td>1</td>
<td>Restored. Mortar box later than frame.</td>
<td>1929</td>
<td></td>
</tr>
<tr>
<td>Golden Lead</td>
<td>L31/29</td>
<td>10</td>
<td>A&amp;G Price</td>
<td>1</td>
<td>Restored</td>
<td>1886</td>
<td>1891</td>
</tr>
<tr>
<td>Johnston’s United</td>
<td>M25/73</td>
<td>20</td>
<td>Langlands (LH battery)</td>
<td>1(RH)1A(LH)</td>
<td>Restored</td>
<td>1870s</td>
<td>1879</td>
</tr>
<tr>
<td>Mt. Greenland</td>
<td>J33/39</td>
<td>10</td>
<td></td>
<td></td>
<td>Intact</td>
<td>1938</td>
<td></td>
</tr>
<tr>
<td>No. 2 South Larry’s</td>
<td>L30/7</td>
<td>10</td>
<td>Moutray, Nelson?</td>
<td>1</td>
<td>Intact</td>
<td>1874?</td>
<td>1892</td>
</tr>
<tr>
<td>Wellington</td>
<td>O28/47</td>
<td>10</td>
<td>Langlands Foundry</td>
<td>1A</td>
<td>Dismantled</td>
<td>1870s</td>
<td>1900</td>
</tr>
<tr>
<td>Welcome Jack</td>
<td>T11/693</td>
<td>5</td>
<td>Union iron Works, SF.</td>
<td>4</td>
<td>Intact</td>
<td>1900</td>
<td></td>
</tr>
<tr>
<td>Ex-Golden Bar</td>
<td></td>
<td>2</td>
<td>Union Iron Works, SF.</td>
<td>3</td>
<td>Portable. Display at Canvastown</td>
<td>1940s</td>
<td></td>
</tr>
<tr>
<td>Ex Four-in-Hand</td>
<td></td>
<td>2</td>
<td>Union Iron Works, S.F.</td>
<td>3</td>
<td>Portable. Display at Coromandel Sch. Mines</td>
<td>1930s</td>
<td></td>
</tr>
<tr>
<td>Ex Moewai</td>
<td></td>
<td>10</td>
<td>Langlands &amp; Co. Melbourne</td>
<td>1</td>
<td>Display at Mercury Bay Museum</td>
<td>1907-08</td>
<td></td>
</tr>
<tr>
<td>Ex Morning Star</td>
<td></td>
<td>5</td>
<td>Langlands Foundry Co.</td>
<td>1</td>
<td>Display at Blacks Point Museum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mayclair Colln.)</td>
<td></td>
<td>10?</td>
<td>Bowes, Scott &amp; Western Ltd. London.</td>
<td>2</td>
<td>Display at Victoria Battery</td>
<td>Post-1896</td>
<td></td>
</tr>
</tbody>
</table>

**Type 1** (Figure 166). This form of post has a square lower section with strengthening webs, a short hexagonal section that carried the camshaft mounts, a round section and then a square cap that carried the top stamp guide. A subset, Type 1A (Figures 167 and 168) is very similar in detail but carries an extra set of bearing mounts for a lineshaft below the camshaft. The Type 1/1A is the most commonly recorded type of iron frame in New Zealand. Thirteen
examples of this pattern were recorded, manufactured by a number of different foundries in New Zealand and Australia (see Table 24). The consistency of the decorative features across posts from a variety of manufacturers is notable.

Figure 166. (Left) Type 1 cast iron battery post.
The Britannia Battery (site L29/15) in 2011. The mortar box was manufactured by A&G Price of Thames, but is almost certainly more recent than the mill frame, the maker of which is unknown.

Figure 167. (Right) Type 1A cast iron battery post.
This is the left hand bank of Johnston’s United Battery (site M25/73) in Nelson, manufactured by Langlands Foundry, Melbourne.

Figure 168. (Left) A dismounted Type 1A battery post, at the Wellington Battery (site O28/47).
It was probably manufactured by the Langlands Foundry in Melbourne.
**Type 2** (Figure 169). This form of post has a straight sided square section, and is much plainer than the Type 1 posts. It is represented by a dismounted pair of posts in the Mayclair Collection held at the Victoria Battery site. They were manufactured by Bowes Scott & Western, Ltd., London.

**Figure 169. Type 2 cast iron battery post.**
This post is 10 inches square and 13 feet 8 ¾ inches tall. The manufacturer’s name, Bowes Scott & Western, is embossed on the post.

**Type 3** (Figure 170). This pattern of frame was used on small portable prospectors’ stamp mills. It consists of two round iron posts mounted in sockets in the sides of the mortar box. The camshaft bearings, lower and upper stamp guides are all mounted on these posts using sliding adjustable housings, and were therefore fully adjustable for height. Two examples were recorded, one on display at the Coromandel School of Mines (Figure 170) and one incorporated into a goldfields display at Canvastown. Both were manufactured by the Union Iron Works, San Francisco. A mill of this pattern is illustrated in Figure 46 in Chapter 5 above.

**Figure 170. Type 3 iron framed prospectors’ mill.**
This small (255 lb stamp) portable stamp mill is on display at the Coromandel School of Mines.
Type 4 (Figure 171). This form consisted of pairs of round cast iron posts linked at the top by a decorative arched casting, creating a 4 post frame. The mortar box was not a separate unit, but consisted of four separate sides mounted on flanges cast into the battery posts, with the screen mounting slots also cast into the posts. Two very similar examples are known, the Battery Creek (Figure 171) (site T12/1410) and Welcome Jack (site T11/693), manufactured respectively by the Pacific Iron Works and the Union Iron Works, both of San Francisco.

Figure 171. Type 4 cast iron battery posts.
A 4 post iron-framed mill with integral mortar box mounting flanges and screen slots. This example is at the Battery Creek Battery (site T12/1410), manufactured by the Pacific Iron Works, San Francisco

The evidence for iron framed stamp mills in New Zealand is therefore good. The majority are variations on one design (Type 1/1A) with a distinctive decorative styling that was manufactured by a number of New Zealand and Australian foundries. The only English-manufactured frame to be identified was notably plain and robust in comparison. The American-manufactured iron frame mills were particularly distinctive, in two well-defined groups. There was therefore a strong international influence in the pattern of iron frames used in New Zealand, but local manufacture was influenced by Australian practice.

Stamp Guides

The archaeological evidence for stamp guides can be divided into two groups; timber guides and iron guides. Timber guides are the most common, with 44 examples identified, and generally simply consist of two timbers set face to face, with a set of half-round grooves in each to accommodate the stamp stems. Iron guides were less common, with just 10 examples identified, but these have a greater variation in design.

Timber guides can be divided into two sub-groups; a pair of basic grooved timbers mounted between the battery frames (Figure 172); or a pair of grooved timbers mounted on heavy guide beams mounted across the battery frames (Figure 173). The guides were often, but not always, made from a durable hardwood that has survived well in the archaeological record.
Iron guides can be similarly divided into two basic sub-groups; those mounted directly across the stamper frame (Figure 174) and those mounted on a guide beam (Figures 175 & 176). Iron guides were usually designed with a single-piece backing plate and individual caps, so that single stamp stems could be removed.
Figure 174. Cast iron top stamp guide at Printz’s Battery in the Longwood Range (site D46/150).

Only 2 example of iron guides mounted on a timber beam were identified (Figures 175 and 176), both on dismantled batteries; the Rise and Shine (from site G42/277) and the Roberts Brothers’ battery (from site T12/704). However photographic evidence suggests that some of the large mills in New Zealand were equipped with this design.

Figure 175. The Rise & Shine battery frame, showing the iron stamp guide mounted on the timber guide beam (Marion Sutton, DoC).

Figure 176. Two iron stamp guide mounts from the Roberts Brothers’ battery (ex-site T12/704).
Overall, the archaeological evidence of stamp guides agrees well with the contemporary engineering literature. The examples illustrated above are very similar to the simpler examples illustrated in Chapter 5 (Figures 48 and 49). The more complex American designs do not appear to have been adopted in New Zealand, the Roberts Brothers’ example (Figure 176) being the most complicated. While it would be expected that iron guides would be more common in heavy mills, the archaeological evidence suggests little correlation between size or weight of mill and the use of timber or iron guides; the heavy Homeward Bound Battery (site F41/477) has timber guides, while the relatively light Printz’s Battery (site D46/150) has iron guides.

**Group 2: The Mortar**

The mortar can be divided into two sections: the mortar foundation (mortar block) and the mortar box itself. Some aspects of the mortar foundation have already been described above in this chapter, particularly when horizontal mortar beams or concrete foundations were employed. This section therefore deals with conventional timber mortar foundations before discussing the full range of mortar boxes.

**Vertical Timber Mortar Blocks**

Vertical timber mortar blocks were the most common form of mortar foundation recorded during the survey with 38 examples recorded, while only 3 certain and 1 possible mortar beams were identified.

Most vertical mortar blocks consisted of a number of heavy timber baulks bolted or clamped together and set on end in the ground. Figure 177 shows a typical example at the Come in Time battery (site G41/251). Another good example is the Garden Gully Battery (site K31/51) in which the eyebolts and through-rods that were used to secure the mortar box are clearly visible (Figure 178).

![Figure 177. Conventional timber mortar blocks at the Come in Time Battery, Bendigo (site G41/251) in 1998.](image-url)
However, details of many mortar blocks are difficult to determine, as they are typically buried with only the very top few inches exposed. The most fully-accessible example is the disassembled Alpine Battery (site F42/265) in Otago (Figure 179). These are built up from five timber baulks, to make blocks that are 5 feet wide, 17 inches thick and 5 feet high. This height is at the lower end of the 4 to 20 feet range that Gordon (1906: 375) stated was typical. They are clamped together with long horizontal rods attached to flat bars across each end, and were originally set in the ground resting on a horizontal bed log.

The use of anvil-blocks between the mortar block and mortar box was described in Chapter 5, but no in situ examples were found. An anvil block is on display outside the Waihi Museum, and presumably came from one of the large batteries that once existed in that town.
The Mortar Box

The mortar box is typically a large iron casting or fabricated unit large enough to accommodate between 1 and 5 stamps. As already observed there is a bias in the archaeological record towards the large and robust elements of stamp mills, and this is certainly the case with mortar boxes, which are well-represented. During the field survey some 126 were recorded in association with a specific site or machines, and at least another 18 sitting loose in various collections.

The mortar box can be described in a number of ways; material of construction; method of construction; size; internal design features; number of outlets; and screen mount; all of which can be recorded from archaeological observations. The weights of the boxes were sometimes discussed by contemporary authors, but it is not possible to measure this in the field. These different criteria are described below in order, but it must be remembered that they all overlap considerably.

Material

Three materials were used in the construction of mortar boxes: cast iron, iron or steel plate, and timber. Of these, cast iron was by far the most common and timber the least common.

Timber Mortar Boxes

Two surviving batteries in New Zealand have evidence of the use of timber in mortar box construction, these being Printz’s Battery (site D46/150) in Southland and the Pleasant Creek Battery (site E41/82) at Skippers.

Printz’s Battery has short cast iron mortar boxes that probably had timber top extensions, based on examination of the only known contemporary photograph of the battery (Figure 180) and inspection of the mortar boxes themselves. These have a recess cast around the top to accommodate an upper box section (Figure 181), although all of the timber elements of this battery, including the frame, have decayed away. This mill was bought second hand in 1880 from the Coromandel, and may have been manufactured in the late 1860s, as it matches very closely descriptions of mills in use at Thames in 1867 (Thames Miner’s Guide 1868: 93).

Figure 180. Detail of an 1880 photograph of Printz’s Battery under construction, showing the two mortar boxes with extended tops (Hall-Jones 1982).
‘Tiger’ Beale’s single stamp water-powered Pleasant Creek Battery (site E41/82) used a timber mortar box (Figure 182), although this has now almost completely decayed away, with just some iron uprights remaining (Figure 183). As a late (1930s or 1940s) battery this is not an example of early battery practice, but rather of improvisation in a small-scale operation built using scavenged equipment and materials.

Figure 182. ‘Tiger’ Beale’s Pleasant Creek Battery (site E41/82) at Skippers in the 1970s (E. Warburton).

Figure 183. The remains of the Pleasant Creek Battery mortar box in 2011.
Iron Mortar Boxes

All other recorded mortar boxes are constructed from either cast iron or a mixture of cast and plate iron, with a few exceptions that were fabricated from steel plate. The majority of mortar boxes are one-piece iron castings, of a wide variety of designs, but ‘sectional’ mortar boxes make up a substantial subset.

Sectional Mortar Boxes

Eighteen battery sites equipped with sectional mortar boxes of various patterns were recorded during the archaeological survey (Table 25). These mortar boxes consisted of numerous parts, and the most common pattern is a cast iron lower half (including the outlets and screen mounts), with a plate iron upper section. Examples of this basic pattern of between 2 and 5 stamps were recorded (Figures 184 to 186).

Table 25. Stamp mills with sectional mortar boxes.
Date (a) is the date of manufacture of the main components (when known), Date (b) is the date of erection at the last working site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA no</th>
<th>Stamps</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alta</td>
<td>G41/253</td>
<td>5</td>
<td>?</td>
<td>1902</td>
</tr>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>2</td>
<td>1887</td>
<td>1887</td>
</tr>
<tr>
<td>Battery Ck.</td>
<td>T12/1410</td>
<td>5</td>
<td>1889</td>
<td>1899</td>
</tr>
<tr>
<td>Come in Time</td>
<td>G41/251</td>
<td>10 (2x5)</td>
<td>?</td>
<td>1907</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>H44/745</td>
<td>5</td>
<td>1876</td>
<td>1917</td>
</tr>
<tr>
<td>Crystal</td>
<td>E41/91</td>
<td>4</td>
<td>?</td>
<td>1936</td>
</tr>
<tr>
<td>Culliford</td>
<td>M28/4</td>
<td>4</td>
<td>?</td>
<td>1871</td>
</tr>
<tr>
<td>Currie’s</td>
<td>E40/24</td>
<td>5</td>
<td>?</td>
<td>ca1941</td>
</tr>
<tr>
<td>Heart of Oak</td>
<td>F42/95</td>
<td>10</td>
<td>1871</td>
<td>1871</td>
</tr>
<tr>
<td>McNichol’s</td>
<td>E40/34</td>
<td>3</td>
<td>?</td>
<td>1948</td>
</tr>
<tr>
<td>Moonlight</td>
<td>K31/10</td>
<td>8 (2x4)</td>
<td>1869</td>
<td>1869</td>
</tr>
<tr>
<td>Nugget*</td>
<td>F41/23</td>
<td>10 (2x5)</td>
<td>1902</td>
<td>1902</td>
</tr>
<tr>
<td>Phoenix</td>
<td>E40/40</td>
<td>30 (6x5)</td>
<td>1866</td>
<td>1866</td>
</tr>
<tr>
<td>Premier</td>
<td>F41/471</td>
<td>30 (6x5)</td>
<td>?</td>
<td>1878 (&amp; later)</td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>2</td>
<td>?</td>
<td>1902</td>
</tr>
<tr>
<td>Smith’s Gully</td>
<td>F42/101</td>
<td>2</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Southberg’s</td>
<td>E40/43</td>
<td>16 (4x8)</td>
<td>1865</td>
<td>1865</td>
</tr>
<tr>
<td>Welcome Jack</td>
<td>T11/693</td>
<td>5</td>
<td>?</td>
<td>1900</td>
</tr>
</tbody>
</table>

*The earlier mortar boxes discarded at the Nugget site are also sectional boxes.
Figure 184. One of the 5 stamp sectional mortar boxes at the Phoenix/Achilles Battery (site E40/40).

Figure 185. The disassembled 2 stamp mortar box at the Smith’s Gully Battery (site F42/101) in 2010.

The Red Queen (site L28/24) beside the Mohikanui River was the only example found of the ‘sandwich’ type of sectional construction illustrated in Figure 60 in Chapter 5. The mortar box consists of 14 separate components, 6 of which are in the base (Figure 186). It was manufactured at the Joshua Hendy foundry in San Francisco.

Figure 186. The mortar box at the Red Queen (site L28/24) in 2011.

Another form of sectional or composite mortar box is found at the Battery Creek Battery (site T12/1410) and the Welcome Jack Battery (site T11/693), that as discussed above are a distinctive pair of American iron framed mills. This form does not have a separate box, but uses flat panels bolted to the four cast iron battery posts, which also carry the screen mounts (Figure 187). The mortar box is therefore integral with the battery frame.
Figure 187. The mortar box mounts on the cast iron battery posts at the Battery Creek Battery (site T12/1410).

As discussed in Chapter 5 above, sectional mortar boxes were designed for use in rugged and mountainous areas where access was difficult. Probably the best archaeological evidence of this intent being realised are the sectional boxes at the two remote and mountainous Bullendale battery sites; the Phoenix/Achilles (Figure 184) and Southberg’s (site E40/43). As with all goldfields machinery, their use was not consistent but was probably often based on availability; the extremely remote Alpha (site B46/42) and Golden Site (site B46/88) mills in Fiordland both used one-piece boxes, while the relatively accessible Come-in-Time Battery (site G41/251) has sectional boxes, acquired second- (or third-) hand from a nearby mill.

Fabricated Steel Plate

Mortar boxes fabricated from welded mild steel plate are not common. A mortar box in the Mayclair Collection at the Victoria Battery site, Waikino, is of a standard 5 stamp slot screen pattern (Figure 188), albeit at the short end of the size range (see discussion below), but its provenance is uncertain. The five single stamp mortars used in the 10 stamp Mt. Greenland Battery (site J33/39) were built by the Dispatch Foundry, Greymouth (J. Staton, Department of Conservation, pers. comm.).

Figure 188. A welded steel mortar box in the Mayclair Collection at the Victoria Battery site, Waikino.
One-Piece Cast Iron Mortar Boxes

This is the most common form of mortar box in the archaeological record, and they come in a wide range of sizes and forms. The most common form is the 5 stamp box with front discharge (Figure 189), but 1, 2, 3 and 4 stamp boxes are also found. They typically have either vertical bolt-on screens or inclined slot-mounted screens (both of which are discussed in detail below). These were made by a variety of manufacturers from New Zealand, Australia, the USA and England.

Figure 189. Typical one-piece cast iron mortar boxes, with mounts for vertical bolt-on screen frames. This pair is part of the Mayclair Collection on display at the Victoria Battery site, Waikino. They were manufactured by A&G Price in Thames in 1875.

Mortar Box Size & Shape

Mortar boxes for from 1 to 5 stamps were recorded during the archaeological survey. Six stamp mortar boxes are known historically to have existed; for example Charles McGill’s battery at Macraes in Otago was a six stamp mill (New Zealand Mines Record, Vol. III, No. 7, 1905); but no archaeological examples have been identified. The physical size of mortar boxes was determined by the diameter of the stamps they housed, allowing for a clearance around each stamp. Stamp sizes are discussed below, but typically they ranged from 6 inches to 10 inches in diameter, with the vast majority (irrespective of overall stamp weight) being between 8 and 9 ½ inches in diameter.

In general, the smaller mortar boxes (1 and 2 stamp) show the greatest variation in form, while the larger boxes show more consistency. Single stamp boxes can be circular or square/rectangular in plan, but all larger sizes are rectangular. Examples of the different construction materials and methods outlined above are found in many of the different size classes.

Single Stamp Boxes

Five batteries equipped with single stamp mortars were recorded (Table 26). The square wooden Pleasant Creek mortar discussed above was a one-off hand-made unit, and the 5 single mortars at the Mt. Greenland Battery were made from sheet steel at the Dispatch Foundry (Figure 191) (J. Station, pers. comm.). The other mortars are all cast iron; two manufactured by Fraser & Tinne in Auckland at the Government Battery in Coromandel and Sawyer’s Battery in Thames (Figure 190); and the round mortars at Fraser’s Gully Battery
(Figure 192) that are based on the form of a ‘dolly pot,’ the mortar and pestle used for hand-crushing samples of ore for assay work.

**Table 26. Overall dimensions and manufacturers of single stamp mortar boxes.**
Note that outside dimensions of the box itself are given, not including the screen mounts, ore feed, etc.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Maker</th>
<th>Length (inches)</th>
<th>Width (inches)</th>
<th>Height (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraser’s Gully</td>
<td>I44/517</td>
<td></td>
<td>19</td>
<td>19</td>
<td>12 ½</td>
</tr>
<tr>
<td>Government, Coromandel</td>
<td>T10/1115</td>
<td>Fraser &amp; Tinne</td>
<td>22 ¾</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Mt. Greenland</td>
<td>J33/39</td>
<td>Dispatch Foundry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pleasant Ck.</td>
<td>E41/82</td>
<td>‘Tiger’ Beale</td>
<td>14</td>
<td>14 ½</td>
<td>Approx 29</td>
</tr>
<tr>
<td>Sawyer’s</td>
<td>T12/1411</td>
<td>Fraser &amp; Tinne</td>
<td>18 ½</td>
<td>18 ¼</td>
<td>46 ½</td>
</tr>
</tbody>
</table>

**Figure 190.** The single stamp mortar box at the Sawyer’s Battery (site T12/1411), Thames.

**Figure 191.** The single mortars at the Mount Greenland Battery (site J33/39) in 1987 (J. Staton, Department of Conservation).

**Figure 192.** Single-stamp mortar at the Fraser’s Gully Battery, Hindon (site I44/517).
Two Stamp Boxes

Nine examples of 2 stamp mortar boxes were recorded (Table 27), and all have a basic rectangular form, but they vary with regard to frame mounting and screen details. There are several main groups, including the two portable prospectors’ batteries manufactured by the Union Iron Works of San Francisco (Figure 193), and the distinctive triple-discharge 2-stamp 4-post mills manufactured by the Joshua Hendy Machine Works and the Union Iron Works, both of San Francisco (Figure 194). The Dunedin-made Arethusa mortar box (from site D46/161, see Figure 163 above) is also distinctive, with its large base plate, but the box section is of similar dimensions to other mills in this class. The Fraser & Chalmers box at the Golden Blocks Battery (Figure 195) also has a wide base, but in other ways is more conventional in design, essentially being a scaled-down version of many 5 stamp boxes. The 2 stamp boxes were used in mills with a wide variety of stamp weights; the Eureka Battery (site E41/51) has 780 lb stamps, while the ex-Four in Hand Battery on display at the Coromandel School of Mines has 255 lb stamps.

Table 27. Overall dimensions and manufacturers of two stamp mortar boxes. Note that outside dimensions of the box itself are given, not including the screen mounts, ore feed, etc.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Maker</th>
<th>Length (inches)</th>
<th>Width (inches)</th>
<th>Height (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>Otago Foundry</td>
<td>23 ¼</td>
<td>13 ½</td>
<td>41 ½</td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>Joshua Hendy, SF.</td>
<td>23</td>
<td>13</td>
<td>45</td>
</tr>
<tr>
<td>Carrick Ra.</td>
<td>F42/101</td>
<td></td>
<td>25</td>
<td>16 ½</td>
<td>41</td>
</tr>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Fraser &amp; Chalmers, England</td>
<td>23</td>
<td>11 ¼</td>
<td>36 ¾</td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>Joshua Hendy, SF.</td>
<td>27</td>
<td>16 ½</td>
<td>48</td>
</tr>
<tr>
<td>Mayclair Colln. Waikino</td>
<td></td>
<td>Joshua Hendy, SF.</td>
<td>26 ¾</td>
<td>16</td>
<td>51</td>
</tr>
<tr>
<td>Govt. Coromandel (display)</td>
<td></td>
<td>Union Iron Works, SF.</td>
<td>26 ½</td>
<td>17</td>
<td>53</td>
</tr>
<tr>
<td>Ex Four in Hand (Coromandel Sch. Mines)</td>
<td></td>
<td>Union Iron Works, SF.</td>
<td>18 3/8</td>
<td>12 ¾</td>
<td>42</td>
</tr>
<tr>
<td>Ex Golden Bar (Canvastown)</td>
<td></td>
<td>Union Iron Works, SF.</td>
<td>18 ½</td>
<td>12 ½</td>
<td>42 ¼</td>
</tr>
</tbody>
</table>
Figure 193. Small 2 stamp prospectors’ battery on display at the Canvastown monument.

Figure 194. Unprovenanced triple-discharge mortar box in the grounds of the Government Battery, Coromandel.

Figure 195. Fraser & Chalmers 2 stamp mortar box at the Golden Blocks Battery (site M25/81).
Three Stamp Boxes

Three stamp mortar boxes also show variety in design. Five examples are recorded (Table 28). Of these, McNichol’s is buried, but some photographs of it are available. The other four are all rectangular, between 27 3/16 inches and 38 ¼ inches long. Printz’s mortar box is discussed above, and is distinctive for its probable composite use of wood. The ‘Riverside’ (Figure 196) and Iris boxes both had side-mounted battery posts. The Bickerton box is of note in this group, as it is the only one of strictly conventional design, being merely a scaled-down version of a standard A&G Price cast iron mortar box. In common with the 2 stamp boxes, the 3 stamp boxes were used for a range of stamp weights.

Table 28. Overall dimensions and manufacturers of 3 stamp mortar boxes.
Note that outside dimensions of the box itself are given, not including the screen mounts, ore feed, etc.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Maker</th>
<th>Length (inches)</th>
<th>Width (inches)</th>
<th>Height (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bickerton</td>
<td>I43/136</td>
<td>A&amp;G Price, 1896</td>
<td>35 ½</td>
<td>15</td>
<td>47</td>
</tr>
<tr>
<td>Iris</td>
<td>T11/625</td>
<td>Fraser &amp; Tinne</td>
<td>37</td>
<td>18 5/8</td>
<td>48 ½</td>
</tr>
<tr>
<td>McNichol</td>
<td>E40/34</td>
<td>Buried</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thames</td>
<td>D46/150</td>
<td>“Riverside”</td>
<td>38 ¾</td>
<td>18 ¼</td>
<td>28 ¼ *</td>
</tr>
<tr>
<td>School Mines</td>
<td>collection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*As discussed above, the Printz mortar box originally had an additional box structure, probably of timber, to add height.

Figure 196. The “Riverside” 3 stamp mortar box in storage at the Thames School of Mines in 2011.

Four stamp Boxes

Four stamp mortar boxes appear to be mainly smaller versions of standardised 5 stamp designs, but the sample size is too small to draw definite conclusions. Of the 5 historic batteries identified with 4 stamp boxes (Table 29), only 2 have boxes that can now be inspected. These are the Culliford (Figure 197) (site M28/4) and Southberg’s (site E40/43),
and the latter are lying on their fronts and can not be fully recorded, but are of a sectional design with cast iron bases and plate iron upper sections. The Crystal Battery (site E41/91) is now destroyed, but photographs taken in the 1990s (Figure 160) show that it also had a sectional mortar box.

Table 29. Overall dimensions and manufacturers of four stamp mortar boxes.
Note that outside dimensions of the box itself are given, not including the screen mounts, ore feed, etc.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Length (inches)</th>
<th>Width (inches)</th>
<th>Height (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Nations</td>
<td>E41/483</td>
<td>Buried</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crystal</td>
<td>E41/91</td>
<td>Missing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culliford</td>
<td>M28/4</td>
<td>39 5/8 in.</td>
<td>12 ¼</td>
<td>40 ½</td>
</tr>
<tr>
<td>Leviathan</td>
<td>E41/89</td>
<td>Missing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southberg’s</td>
<td>E40/43</td>
<td>46 ¾ in.</td>
<td>13 ½</td>
<td>46</td>
</tr>
</tbody>
</table>

Figure 197. The cast iron sectional 4 stamp mortar box at the Culliford Battery (site M28/4) in 2011.

Five Stamp Boxes

Five stamp boxes are the most common form, with 83 individual boxes recorded in detail during the archaeological survey (Table 30), and as such the 5 stamp mill (or its multiples of 10, 15 etc) can be regarded as the typical layout in New Zealand. The 5 stamp mortar boxes vary in details and construction, but generally are less variable in their general design than the smaller mortar boxes. The variation (other than in the composite vs. one piece construction discussed above) is mainly in the number of outlets, type of screen mounts, and internal details such as liners (all discussed below).
Table 30. Five stamp mortar boxes in New Zealand.
(2 parts: see also next page) Manufacturers are shown where known. Length and width are measured across the outside of the upper section of the box, excluding any flanges. Height is the total height of the box, including the base.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Boxes</th>
<th>Maker</th>
<th>Length (in)</th>
<th>Width (in)</th>
<th>Height (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albion</td>
<td>Q27/112</td>
<td>2</td>
<td>Langlands, Melbourne</td>
<td>55 1/8</td>
<td>14 7/8</td>
<td>42 ½</td>
</tr>
<tr>
<td>Alpha</td>
<td>B46/42</td>
<td>2</td>
<td></td>
<td>55</td>
<td>15 ¾</td>
<td>42</td>
</tr>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>2</td>
<td></td>
<td>60 ½</td>
<td>17 ¾</td>
<td>42 ¾</td>
</tr>
<tr>
<td>Alta</td>
<td>G41/253</td>
<td>1</td>
<td></td>
<td>54 ½</td>
<td>16 ¾</td>
<td>48</td>
</tr>
<tr>
<td>Anderson's</td>
<td>F41/473</td>
<td>2</td>
<td></td>
<td>59 ½</td>
<td>18</td>
<td>48 ½</td>
</tr>
<tr>
<td>Battery Ck</td>
<td>T12/1410</td>
<td>1</td>
<td>Manuf. Pacific Iron Works SF. 1889</td>
<td>48 5/8</td>
<td>16 ½</td>
<td>37</td>
</tr>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td>2</td>
<td>A&amp;G Price, Thames, 1896</td>
<td>57</td>
<td>16 ½</td>
<td>55</td>
</tr>
<tr>
<td>Big River</td>
<td>L31/4</td>
<td>2</td>
<td>Dispatch?</td>
<td>62</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>Blacks Pt. Museum</td>
<td></td>
<td></td>
<td>Langlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolitho's/Watts'</td>
<td>L30/174</td>
<td>1</td>
<td>Manuf. A&amp;G</td>
<td>55</td>
<td>14 ¼</td>
<td>42</td>
</tr>
<tr>
<td>Britannia</td>
<td>L29/15</td>
<td>1</td>
<td>A&amp;G Price, Thames, 1896</td>
<td>57 3/8</td>
<td>16 ½</td>
<td>55</td>
</tr>
<tr>
<td>Callery's</td>
<td>H42/161</td>
<td>1</td>
<td></td>
<td>56 ½</td>
<td>15 ½</td>
<td>50</td>
</tr>
<tr>
<td>Canton</td>
<td>H44/831</td>
<td>1</td>
<td></td>
<td>63</td>
<td>17 ¼</td>
<td>48 ½</td>
</tr>
<tr>
<td>Come in Time 1</td>
<td>G41/251</td>
<td>1</td>
<td></td>
<td>54 ½</td>
<td>19 ¼</td>
<td>41</td>
</tr>
<tr>
<td>Come in Time 2</td>
<td></td>
<td>1</td>
<td></td>
<td>55</td>
<td>15</td>
<td>46</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>H44/745</td>
<td>1</td>
<td>Otago Foundry, Dunedin, 1876</td>
<td>49</td>
<td>14</td>
<td>39 ¾</td>
</tr>
<tr>
<td>Croesus</td>
<td>L29/2</td>
<td>2</td>
<td></td>
<td>63</td>
<td>19 ½</td>
<td>48 ½</td>
</tr>
<tr>
<td>Currie's</td>
<td>E40/24</td>
<td>1</td>
<td></td>
<td>56 ½</td>
<td>19 ¼</td>
<td>45</td>
</tr>
<tr>
<td>Garden Gully</td>
<td>K31/51</td>
<td>2</td>
<td></td>
<td>61 ½</td>
<td>17</td>
<td>48</td>
</tr>
<tr>
<td>Golden Blocks 1</td>
<td>M25/81</td>
<td>1</td>
<td>Allis-Chalmers Co. Milwaukee, Wis.</td>
<td>47 ½</td>
<td>12 ¼</td>
<td>47 3/4</td>
</tr>
<tr>
<td>Golden Blocks 2</td>
<td>M25/81</td>
<td>1</td>
<td>A&amp;G Price, Thames, 1899</td>
<td>52 ½</td>
<td>16 ½</td>
<td>47</td>
</tr>
<tr>
<td>Golden Lead</td>
<td>L31/29</td>
<td>2</td>
<td></td>
<td>61 ½</td>
<td>16 ½</td>
<td>47</td>
</tr>
<tr>
<td>Golden Site</td>
<td>B46/88</td>
<td>2</td>
<td></td>
<td>54 7/8</td>
<td>18</td>
<td>45</td>
</tr>
<tr>
<td>Govt Battery Coromandel</td>
<td>T10/1115</td>
<td>1</td>
<td>A&amp;G Price, Thames</td>
<td>56</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Hauraki PA Colln (Victoria?)</td>
<td>T13/300?</td>
<td>1</td>
<td>Martha GMCo Waikino</td>
<td>57</td>
<td>19</td>
<td>53</td>
</tr>
<tr>
<td>Heart of Oak</td>
<td>F42/95</td>
<td>1</td>
<td></td>
<td>47 ½</td>
<td>16 ¼</td>
<td>Incomplet</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>2</td>
<td>Sandycroft Foundry, Chester, England</td>
<td>58</td>
<td>19 ½</td>
<td>66</td>
</tr>
<tr>
<td>Johnston's United 1</td>
<td>M25/73</td>
<td>2</td>
<td>Langlands, Melbourne</td>
<td>55 1/8</td>
<td>14 ¾</td>
<td>42 1/4</td>
</tr>
<tr>
<td>Johnston's United 2</td>
<td>M25/73</td>
<td>2</td>
<td></td>
<td>62 5/8</td>
<td>17 1/8</td>
<td>48 1/4</td>
</tr>
<tr>
<td>Kirwan's Reward</td>
<td>L30/62</td>
<td>3</td>
<td>Dispatch Foundry, Greymouth, 1900</td>
<td>62</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Ex Moewai (Mercury Bay Museum)</td>
<td></td>
<td>2</td>
<td>Langlands, Melbourne</td>
<td>49 ½</td>
<td>13 ½</td>
<td>40</td>
</tr>
<tr>
<td>No. 2 South Larry's</td>
<td>L30/7</td>
<td>2</td>
<td></td>
<td>59 ¾</td>
<td>18</td>
<td>48 ½</td>
</tr>
<tr>
<td>Site</td>
<td>NZAA No.</td>
<td>Boxes</td>
<td>Maker</td>
<td>Length (in)</td>
<td>Width (in)</td>
<td>Height (in)</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------</td>
<td>-------</td>
<td>------------------------------------------</td>
<td>-------------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Nugget (in retaining wall)</td>
<td>F41/23</td>
<td>2</td>
<td>Fraser &amp; Chalmers Ltd., Erith, England. 58G</td>
<td>47</td>
<td>16 ¼</td>
<td>40 ½</td>
</tr>
<tr>
<td>Nugget (loose on site)</td>
<td>F41/23</td>
<td>2</td>
<td>Incompl ete</td>
<td>46 ¼</td>
<td>15</td>
<td>Incompl ete</td>
</tr>
<tr>
<td>Nugget (standing)</td>
<td>F41/23</td>
<td>2</td>
<td>Phoenix/Achilles</td>
<td>53 ½</td>
<td>14</td>
<td>52</td>
</tr>
<tr>
<td>Premier/Maryborough 1</td>
<td>F41/471</td>
<td>1</td>
<td>Premier/Maryborough</td>
<td>54 ½</td>
<td>15</td>
<td>41 ½</td>
</tr>
<tr>
<td>Premier/Maryborough 2</td>
<td>F41/471</td>
<td>1</td>
<td>Incompl ete</td>
<td>56 ¼</td>
<td>17</td>
<td>Incompl ete</td>
</tr>
<tr>
<td>Rise &amp; Shine</td>
<td>G41/277</td>
<td>1</td>
<td>Serpentine 1</td>
<td>56 ½</td>
<td>17</td>
<td>47</td>
</tr>
<tr>
<td>Serpentine 1</td>
<td>H42/2</td>
<td>1</td>
<td>Serpentine 2</td>
<td>55</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Serpentine 2</td>
<td>H42/2</td>
<td>1</td>
<td>Taitapu</td>
<td>55</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Thames town sign 1</td>
<td></td>
<td></td>
<td>Thames town sign 1</td>
<td>56</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>Thames town sign 2</td>
<td></td>
<td></td>
<td>Thames town sign 2</td>
<td>56</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>United Goldfields 1</td>
<td>F41/484</td>
<td>1</td>
<td>United Goldfields 1</td>
<td>55</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>United Goldfields 2</td>
<td>F41/484</td>
<td>1</td>
<td>United Goldfields 2</td>
<td>57 ¼</td>
<td>16 ½</td>
<td>55</td>
</tr>
<tr>
<td>Victoria (Mayclair Colln)</td>
<td></td>
<td></td>
<td>Victoria (Mayclair Colln)</td>
<td>54</td>
<td>16</td>
<td>47</td>
</tr>
<tr>
<td>Victoria (Mayclair Colln)</td>
<td></td>
<td></td>
<td>Victoria (Mayclair Colln)</td>
<td>41 ½</td>
<td>15 ¼</td>
<td>45</td>
</tr>
<tr>
<td>Victoria (Mayclair Colln)</td>
<td></td>
<td></td>
<td>Victoria (Mayclair Colln)</td>
<td>51</td>
<td>15</td>
<td>44 ¾</td>
</tr>
<tr>
<td>Victoria (Mayclair Colln)</td>
<td></td>
<td></td>
<td>Victoria (Mayclair Colln)</td>
<td>55</td>
<td>16</td>
<td>47 ½</td>
</tr>
<tr>
<td>Waimea</td>
<td>M28/5</td>
<td>2</td>
<td>Waimea</td>
<td>54 ½</td>
<td>15</td>
<td>44 3/8</td>
</tr>
<tr>
<td>Welcome Jack</td>
<td>T11/693</td>
<td>1</td>
<td>Welcome Jack</td>
<td>55</td>
<td>14 ¾</td>
<td>42</td>
</tr>
<tr>
<td>Wellington</td>
<td>O28/47</td>
<td>2</td>
<td>Wellington</td>
<td>49 ½</td>
<td>15</td>
<td>42</td>
</tr>
</tbody>
</table>

As discussed in Chapter 5 above, the contemporary engineering literature stated that mortar box size was not directly affected by stamp weight, but rather by stamp head diameter, but the weight of mortar boxes should be proportional to the weight of the stamps. This is supported by the archaeological evidence. Taking just one dimension, the overall length of the boxes, they range from 46 ¾ inches to 63 inches long, but the heaviest batteries do not use the largest boxes, nor the lightest batteries the smallest. For example, the Homeward Bound mortar boxes (for 1120 lb stamps) are 58 inches long (Figure 198), while the Canton (with 490lb stamps) has the longest box, at 63 inches (Figure 199). However, if the height of the mortar boxes is also taken into account, the effect of stamp weight can be seen, as the Homeward Bound has the tallest recorded boxes at 66 inches high, including approximately 13 inches of solid iron in the base.

30 The fabricated sheet steel box in the Mayclair Collection is only 41 ½ inches long, but its lack of provenance, unknown number of stamps (5 is an assumption because it looks that size) and unusual construction (it is the only known large box of this construction) means it was excluded from the calculations.
Figure 198. The left hand Homeward Bound (site F41/477) mortar box. This represents the heaviest surviving form of the typical 5 stamp mortar in New Zealand.

Figure 199. The Canton (site H44/831) mortar box in 2010
This is the longest mortar box recorded (63 inches), but carried relatively light stamps (490lb).

Gordon (1906: 378) stated that the ‘principal design of mortar used in New Zealand is the Homestake pattern, which is 58 ¼ inches in height and 28 ¼ inches wide, having a length of base of 56 ¾ inches and weighing about 3 tons 6 cwt.’ As discussed in Chapter 5, the ‘Homestake’ mortar was generally a high narrow mortar designed for rapid crushing (Liddel 1945: 303). The archaeologically observed range of mortar box lengths (Table 30) sit well with Gordon’s figures, although most boxes are somewhat shorter. This is possibly a product of the archaeological bias towards smaller mills discussed in Chapter 7. The heaviest boxes (the Homeward Bound and Taitapu boxes) are probably more typical of the larger mills that once existed, and agree very well with Gordon’s figures. The only possible surviving mortar
box (Figure 200) from the 200 stamp Victoria Battery at Waikino (site T13/300) is 5 inches shorter than Gordon’s figures, but otherwise matches them closely.

**Figure 200. Heavy 5 stamp mortar box manufactured at Waikino by the Martha Gold Mining Co.**

**Mortar Box Design Details**

**Inside Amalgamation**

The use of inside amalgamation in mortar boxes is difficult to identify in the archaeological record, especially if it was carried out by simply adding free mercury to an otherwise standard box. It is known from historical sources that the Homeward Bound Battery (site F41/477) used inside amalgamation plates (*New Zealand Mines Record*, 1899 Vol. III No. 4: 143), and the boxes at this site have a distinctive design with a full-width flare at the rear (which is difficult to photograph at this site) where the plates were mounted. A number of similar boxes with the same full-length flare were made by A.&G. Price in Thames, one example being the boxes at the 1910 Bendigo Battery (site T13/90) in the Waiorongomai Valley (Figures 201 and 202).

**Figure 201. Interior of mortar box at the Bendigo Battery (site T13/90), Waiorongomai, showing the full-width flare where amalgamation plates were probably mounted.**
Figure 202. End view of the exterior of the Bendigo mortar box, showing the rear full-width flare (to the left in this view).

As discussed in Chapter 5, widening of the mortar box at the screen level was a characteristic of the inside-amalgamating box (Del Mar 1912: 22; Truscott 1923: 142). If the shape of the Bendigo Battery mortar box can be regarded as being intended to allow the use of inside amalgamation, 8 other possible examples with a similar box shape can be identified (Table 31). All of these boxes for which date of manufacture are known post-date 1890, and all have slot-screen mounts (see below).

Table 31. Sites with mortar boxes possibly designed for internal amalgamation.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA no.</th>
<th>Manufacturer</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td>A&amp;G Price</td>
<td>1896</td>
<td>1910</td>
</tr>
<tr>
<td>Britannia</td>
<td>L29/15</td>
<td>A&amp;G Price</td>
<td></td>
<td>1929</td>
</tr>
<tr>
<td>Callery’s</td>
<td>I42/161</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Allis-Chalmers</td>
<td></td>
<td>1911</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>Sandycroft</td>
<td>1899</td>
<td>1910</td>
</tr>
<tr>
<td>Robert’s Bros.</td>
<td>Ex T12/704</td>
<td>Martha GMCo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>Fraser &amp; Chalmers</td>
<td>1896</td>
<td>1897</td>
</tr>
<tr>
<td>United Goldfields</td>
<td>F41/484</td>
<td>A&amp;G Price</td>
<td>1898</td>
<td>Pre-1916</td>
</tr>
</tbody>
</table>

Inside Liners

Many mortar boxes show signs of internal wear due to the splash of pulp from the stamps (Figure 203), and some boxes, such as the Big River units (site L31/4) had worn right through in places. Evidence for the use of protective inside linings was identified in 11 batteries (20 mortar boxes), either in the form of the linings themselves (Figure 204), or in the mounting holes (Figure 205).

Figure 203. Wear from the splash of pulp on the interior of a mortar box at the Premier/Maryborough Battery (site F41/471).
Figure 204. Looking inside an Alpine Battery (site F42/265) mortar box, with rear and ore chute liners in place.

Figure 205. (Right) Side view of one mortar box at the Wellington Battery (site O28/47). The four bolts on the side secure an internal liner.

The linings often covered the back and sides of the mortar box, although in the Waimea (site M28/5) only the middle 2/3 of the rear was covered, while the Red Queen (site L28/24) and Rise and Shine (site G41/277) had plates only on their ore feeds. The full width linings at Johnston’s United Battery (site M25/73) were 18 inches deep and 7/16 in. thick, and discarded liners at the site had been worn right through.

**Outlets**

The number of outlets in a mortar box can be anywhere between 1 and 4 (front only; front and rear; front and sides; front, sides and rear). By far the most common pattern is the front discharge, and only 13 mortar boxes with multiple outlets were recorded (Table 32).

The only double discharge (front and back) mortar boxes recorded are at the No. 2 South Larry’s Battery near Reefton. Triple discharge (front and sides) mortars are more common, and fall into two main categories; the group of American 2-stamp 4-post triple discharge mills (already discussed above), and the ex-Moewai Battery now on display at the Mercury Bay Museum (Figure 206). Quadruple outlets are found at the very similar Welcome Jack and Battery Creek mills, a set of discarded boxes at the Nugget and the right hand box at the Serpentine Battery (Figure 207). The latter has channels cast around the box to carry the pulp to the front.
Table 32. Multiple-discharge mortar boxes in New Zealand.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Maker</th>
<th>Stamps/box</th>
<th>Outlets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Ck</td>
<td>T12/1410</td>
<td>Pacific iron Works, SF</td>
<td>5</td>
<td>Front, sides, rear</td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>Joshua Hendy, SF</td>
<td>2</td>
<td>Front, sides</td>
</tr>
<tr>
<td>Ex-Moewai (Mercury Bay Museum)</td>
<td></td>
<td>Langlands, Melbourne</td>
<td>5</td>
<td>Front, sides</td>
</tr>
<tr>
<td>No. 2 South Larry’s</td>
<td>L30/7</td>
<td>Moutray, Nelson, NZ</td>
<td>5</td>
<td>Front, rear</td>
</tr>
<tr>
<td>Nugget (old boxes)</td>
<td>F41/23</td>
<td>(Melbourne)</td>
<td>5</td>
<td>Front, sides, rear</td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>Joshua Hendy, SF</td>
<td>2</td>
<td>Front, sides</td>
</tr>
<tr>
<td>Serpentine (RH box)</td>
<td>H42/2</td>
<td>Union Iron Works, SF</td>
<td>5</td>
<td>Front, sides, rear</td>
</tr>
<tr>
<td>Welcome Jack</td>
<td>T11/693</td>
<td>Union Iron Works, SF</td>
<td>5</td>
<td>Front, sides, rear</td>
</tr>
<tr>
<td>Mayclair Colln.</td>
<td></td>
<td>Joshua Hendy SF</td>
<td>2</td>
<td>Front, sides</td>
</tr>
<tr>
<td>Gvt. Battery Coromandel, display</td>
<td></td>
<td>Union Iron Works, SF</td>
<td>2</td>
<td>Front, sides</td>
</tr>
</tbody>
</table>

Several things can be noted about the multiple-discharge mortar boxes that do survive. Most of them were manufactured in Australia or America, with only one confirmed NZ example, and one unknown. It is known that the first major battery erected in the Otago goldfields, the 1864 ten stamp OPQ Battery at Waipori was manufactured by the Carlton Foundry in Melbourne, and was equipped with front, rear and side discharge mortar boxes (Otago Witness, 18 June 1864: 16). The archaeological evidence is that multiple discharge mortar boxes did continue to be used, but generally failed to find favour. As discussed in Chapter 5 above, contemporary comments were that such boxes were good in theory but not ideal in practice. In support of this, the Serpentine mortar had its extra outlets blocked to make it operate as a single-discharge (in the

Figure 206. Triple-discharge (front and sides) mortar box on the Moewai Battery, at the Mercury Bay Museum.

Figure 207. (Right) The rear of the right hand mortar at the Serpentine Battery (site H42/2).
fashion described by Louis 1902: 149), while the multiple discharge boxes at the Nugget Battery had been discarded and the replacement boxes were conventional single-discharge.

**Screen Mounts**

There are two basic methods of mounting screens on mortar boxes; vertical screens that were bolted or clamped on (Figure 208); and inclined screens that were mounted in slots (Figure 209). Vertical screen mount boxes typically have the front outlet divided in two (only one exception to this was recorded), and took two small screens. Incline slot mortar boxes have a single wide outlet that took a screen in a timber frame. Both types are common, although with a distinctly larger number of the vertical mounts (Table 33).

**Table 33. The distribution of vertical clamp-on screens and inclined slot screens by size of mortar box.**

<table>
<thead>
<tr>
<th>Stamps</th>
<th>Vertical clamp</th>
<th>Inclined slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>52</td>
<td>31</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>67</strong></td>
<td><strong>41</strong></td>
</tr>
</tbody>
</table>

*Figure 208. (Left) A.&G. Price mortar box dated 1875 with vertical screen mounts, on display at the Victoria Battery site, Waikino.*

*Figure 209. (Right) A.&G. Price mortar box dated 1898 with inclined slot screen mounts at the United Goldfields Battery (site F41/484), Macetown.*

When the use of screen mounting is tested against the manufacturer and date of manufacture (Table 34) some patterns become apparent. All of the recorded and identifiable mortar boxes with vertical clamp-on screens are of New Zealand or Australian manufacture, while US and
UK makers are only represented by inclined slot mounted screens. New Zealand manufacturers did produce both types of screen, and dated boxes by A.&G. Price suggest that early boxes (1870s) had vertical mounts (Figure 208), while later boxes (1890s) had inclined slot mounts (Figure 209). This pattern of a progression from vertical to incline slot mounts can also be seen at the Nugget Battery (site F41/23), where the standing 1903 mill has mortar boxes with incline mounts, while the discarded earlier boxes at the site have vertical mounts.

Table 34. The distribution of mortar boxes with vertical and inclined screens by manufacturer, country of manufacture and date of manufacture, where these can be confidently determined.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Country</th>
<th>Year</th>
<th>Vertical clamp</th>
<th>Inclined slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allis-Chalmers</td>
<td>USA</td>
<td>ca1911</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Bowes Scott &amp; Western</td>
<td>UK</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Chas. Judd</td>
<td>NZ</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Dispatch Foundry</td>
<td>NZ</td>
<td>1900</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Fraser &amp; Chalmers</td>
<td>UK</td>
<td>1897</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Fraser &amp; Chalmers</td>
<td>UK</td>
<td>1898</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fraser &amp; Tinne</td>
<td>NZ</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joshua Hendy</td>
<td>USA</td>
<td>7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Langland Foundry</td>
<td>Aus</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martha G.M.Co.</td>
<td>NZ</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Masefield &amp; Co.</td>
<td>NZ</td>
<td>1874</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Moutray, Nelson</td>
<td>NZ</td>
<td>1874</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pacific Iron Works</td>
<td>USA</td>
<td>1889</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>A.&amp;G. Price</td>
<td>NZ</td>
<td>n.d.</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>A.&amp;G. Price</td>
<td>NZ</td>
<td>1875</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>A.&amp;G. Price</td>
<td>NZ</td>
<td>1896</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>A.&amp;G. Price</td>
<td>NZ</td>
<td>1898</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>A.&amp;G. Price</td>
<td>NZ</td>
<td>1899</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sandycroft</td>
<td>UK</td>
<td>1899</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Union Iron Works</td>
<td>USA</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W. Wilson, Otago</td>
<td>NZ</td>
<td>1876</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>W. Wilson, Otago</td>
<td>NZ</td>
<td>1887</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The available archaeological evidence is therefore that there was a transition over time from the use of vertical mount screens to inclined screens, particularly in the larger mills. Australian and New Zealand manufactured mortar boxes show this change over time, but all surviving American and British boxes are of the later incline slot type. Older type mortar boxes continued in use for many years as old batteries were moved and parts recycled, and an example of this can be seen at the early twentieth century United Goldfields Battery (site F41/484) at Macetown that has one mortar box of each type.

**Screens**

The screens that were mounted on the mortar boxes are much less durable than the boxes, and very little evidence remains of either the screen frames for slot-mounting or the screen material for either mounting method. Vertical bolt or clamp secured screens were held against the front of the mortar box by small frames, of which the surviving examples are made of wrought iron (Figure 210). Screens for slot mounts were generally held in wooden frames, but only one original and intact example was recorded, on the 3-stamp unprovenanced ‘Riverside’ mortar box held in the Thames School of Mines collection (Figure 211). This is a wooden
frame with simple bridle joints on the corners secured by wooden dowels. One example of an iron frame was recorded at the Battery Creek Battery (site T12/1410), which has a rebate on one side to carry the screen material (Figure 212).

Figure 210. The right hand mortar box at the Come in Time Battery (site G41/251) in 1998. This box has vertical screen mounts, with parts of the screen frames still present.

Figure 211. Wooden screen frame in the ‘Riverside’ mortar box.

Figure 212. A cast iron screen frame at the Battery Creek Battery (site T12/1410).

The screens themselves were of lightweight materials and have tended not to survive well on battery sites. One almost complete screen was found together with some other fragments at the Premier/Maryborough Battery (site F41/471). These were of two sorts; punched iron sheet and a woven iron wire gauze. The fragment of iron wire gauze was too corroded to measure accurately, but the punched screen was in better condition (Figure 213). It had 13 holes to the linear inch (approximately 169 holes per square inch), and the holes were approximately 1/32 inch (0.03 inch, 0.8mm) in diameter.31 The screen fitted perfectly into one outlet in the only complete mortar box still on the site (Figure 213). An 1898 description of the mill stated that punched Russia iron was used, with 189-200 holes to the square inch (AJHR 1898 C3: 100), and the archaeological evidence agrees reasonably closely with this. It is of note that the

31 The hole size and distribution was measured on-site using a vernier caliper, without any magnification.
Premier/Maryborough screen is finer than the range that Gordon (1906: 386) stated was generally used in New Zealand (see Table 4 in Chapter 5).

Figure 213. Punched iron sheet screen at the Premier/Maryborough Battery (site F41/471), Macetown, in 2010.
Group 3: The Lifting Mechanism

The Camshaft

Sixty-one camshafts were measured during the archaeological survey, ranging in diameter from 2 ½ inches in the ‘Riverside’ mill held by the Thames School of Mines to 6 inches at the Homeward Bound (site F41/477) and Cherry & Sons (site T13/294) mills. Several standardised sizes were recorded, in particular 3 7/8 inch diameter (17 examples) and 4 7/8 inch diameter (8 examples).

As discussed in Chapter 5, contemporary accounts stated that camshaft diameter was proportional to stamp weight. To test this against the archaeological evidence, the sample of 16 calculated stamp weights was tabulated with the relative camshaft diameters (Table 35), and the results show a very clear correlation. The Eureka and Iris mills have smaller camshafts than expected for their stamp weights, but this might be explained by the Eureka being a 2 stamp mill and the Iris being a 3 stamp mill, and therefore their camshafts were short and rigid and would not have picked up more than 2 stamps at any time.

Table 35. Camshaft diameters and calculated stamp weights from a sample of 16 surviving stamp mills.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Camshaft Dia. (inches)</th>
<th>Stamp weight (pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex Roberts Bros.</td>
<td>Ex T12/704</td>
<td>6</td>
<td>1240</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>6</td>
<td>1120</td>
</tr>
<tr>
<td>Govt. Coromandel</td>
<td>T10/1115</td>
<td>5 ¼</td>
<td>1030</td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td>5</td>
<td>840</td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>5</td>
<td>830</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>4 7/8</td>
<td>720</td>
</tr>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>4 7/8</td>
<td>685</td>
</tr>
<tr>
<td>No. 2 South Larry’s</td>
<td>L30/7</td>
<td>4 ¼</td>
<td>670</td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>4 7/16</td>
<td>780</td>
</tr>
<tr>
<td>Iris</td>
<td>T11/625</td>
<td>4 5/16</td>
<td>740</td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/25</td>
<td>3 7/8</td>
<td>565</td>
</tr>
<tr>
<td>Canton</td>
<td>H44/831</td>
<td>3 7/8</td>
<td>490</td>
</tr>
<tr>
<td>Albion</td>
<td>Q27/112</td>
<td>3 7/8</td>
<td>480</td>
</tr>
<tr>
<td>Moewai (Mercury Bay Museum)</td>
<td></td>
<td>3 5/16</td>
<td>415</td>
</tr>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>3 3/16</td>
<td>400</td>
</tr>
<tr>
<td>Four in Hand (Coro. Sch. Mines)</td>
<td></td>
<td>3</td>
<td>255</td>
</tr>
</tbody>
</table>

This data can also be compared with the contemporary recommended and reported measurements as given by Wiard (1915) and Richards (1906) and summarised in Chapter 5 above. This comparison is given in Table 36.
Table 36. Camshaft diameters for various weights of stamps from Wiard (1915) and Richards (1906), compared to the New Zealand archaeological evidence.

<table>
<thead>
<tr>
<th>Stamp weight (lbs)</th>
<th>Shaft dia. (inches) (Wiard 1915)</th>
<th>Shaft dia. (inches) (Richards 1906)</th>
<th>Shaft dia. (inches) NZ arch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>255</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td></td>
<td>3 3/16</td>
<td></td>
</tr>
<tr>
<td>415</td>
<td></td>
<td>3 5/16</td>
<td></td>
</tr>
<tr>
<td>480</td>
<td></td>
<td>3 7/8</td>
<td></td>
</tr>
<tr>
<td>490</td>
<td></td>
<td>3 7/8</td>
<td></td>
</tr>
<tr>
<td>560</td>
<td></td>
<td>3 7/8</td>
<td></td>
</tr>
<tr>
<td>650</td>
<td></td>
<td>4 3/8, 5</td>
<td></td>
</tr>
<tr>
<td>685</td>
<td></td>
<td>4 7/8</td>
<td></td>
</tr>
<tr>
<td>720</td>
<td></td>
<td>4 7/8</td>
<td></td>
</tr>
<tr>
<td>750</td>
<td></td>
<td>5 ½, 6</td>
<td></td>
</tr>
<tr>
<td>780</td>
<td></td>
<td>4 15/16</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>5, 5 ¼</td>
<td></td>
</tr>
<tr>
<td>850</td>
<td>5 3/8</td>
<td>5, 5 ½, 4 ½ to 5 ½</td>
<td></td>
</tr>
<tr>
<td>900</td>
<td>5 3/8</td>
<td>5 ½</td>
<td></td>
</tr>
<tr>
<td>930</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>950</td>
<td>5 ½</td>
<td>5 3/8</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>5 ¼</td>
<td>5 ½</td>
<td></td>
</tr>
<tr>
<td>1050</td>
<td>6</td>
<td>5 ¾</td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td></td>
<td>5 7/8</td>
<td></td>
</tr>
<tr>
<td>1150</td>
<td>6 ½</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1250</td>
<td>6 15/16</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>6 15/16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td>6 15/16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>6 15/16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of this comparison show that New Zealand practice was close to international practice, with a possible tendency to use slightly lighter camshafts. The skewing of the table to show mainly light New Zealand Mills and heavy overseas mills is due to the combined effect of the focus of the literature on larger mills and the archaeological bias towards smaller mills (discussed in Chapter 7).

The mounting of camshafts was straightforward, using bearing blocks mounted either on the battery posts or cam beam. Bearings on iron-frame mills were generally integral with the battery posts (Figure 214). Most camshaft bearings were lined with babbit metal or copper alloy.

Figure 214. The camshaft bearing mount on Anderson’s Battery (site F41/473).
Camshaft position could either be behind or in front of the stamps. In the archaeological sample 33 front mounted and 10 rear mounted camshafts were identified. This appears to have been a clear matter of choice, as many frames could be mounted either way around (with the obvious exception of the cast iron frames with integral bearing mounts (Figure 214).

**The Cam**

The universal form of cam recorded in New Zealand stamp mills is the two-arm iron or steel cam (Figure 215). While this basic form is consistent, there is a wide variation in detail, particularly in the robustness and length of the arms.

![Discarded cam at the Ajax Battery (site L30/31), near Reefton. This shows the basic form of the standard cam, with a robust hub and two curved arms. The scale is 2 feet (24 inches) long.](image)

Cams from 58 stamp mills were measured, and ranged in size from 17 ½ inches to 34 inches tip to tip, although the majority were between 24 inches and 33 inches tip to tip. Table 37 gives the cam dimensions at the 16 mills for which stamp weight were calculated. The contemporary literature discussed in Chapter 5 stated that cam size was related to drop height and not stamp weight, and this is generally supported by the archaeological evidence. Although there is an overall trend towards larger diameter cams in heavier mills, this is probably because all parts are slightly larger to accommodate the greater weights and clearances.
Table 37. Cam sizes (tip to tip) in relation to stamp weight and camshaft diameters for a sample of 16 stamp mills.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Camshaft Dia (inches)</th>
<th>Stamp weight (pounds)</th>
<th>Cam size (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex Roberts Bros. (Hauraki P.A.)</td>
<td>Ex T12/704</td>
<td>6</td>
<td>1240</td>
<td>31</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>6</td>
<td>1120</td>
<td>32</td>
</tr>
<tr>
<td>Govt. Coromandel</td>
<td>T10/1115</td>
<td>5 ¼</td>
<td>1030</td>
<td>31 ¼</td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td>5</td>
<td>840</td>
<td>34</td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>5</td>
<td>830</td>
<td>31 ½</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>4 7/8</td>
<td>720</td>
<td>27</td>
</tr>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>4 7/8</td>
<td>685</td>
<td>28 7/8</td>
</tr>
<tr>
<td>No. 2 South Larry’s</td>
<td>L30/7</td>
<td>4 ¾</td>
<td>670</td>
<td>33 ¾</td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>4 7/16</td>
<td>780</td>
<td>26 ½</td>
</tr>
<tr>
<td>Ex Iris (at Opiotoui)</td>
<td>Ex T11/625</td>
<td>4 5/16</td>
<td>740</td>
<td>26 5/16</td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/25</td>
<td>3 7/8</td>
<td>565</td>
<td>25 7/8</td>
</tr>
<tr>
<td>Canton</td>
<td>H44/831</td>
<td>3 7/8</td>
<td>490</td>
<td>29</td>
</tr>
<tr>
<td>Albion</td>
<td>Q27/112</td>
<td>3 7/8</td>
<td>480</td>
<td>27 7/8</td>
</tr>
<tr>
<td>Ex Moewai (Mercury Bay Museum)</td>
<td>D46/161</td>
<td>3 5/16</td>
<td>415</td>
<td>28 7/16</td>
</tr>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>3 3/16</td>
<td>400</td>
<td>30 3/16</td>
</tr>
<tr>
<td>Ex Four in Hand (Coro. Sch. Mines)</td>
<td>Q27/112</td>
<td>3 3/16</td>
<td>400</td>
<td>30 3/16</td>
</tr>
</tbody>
</table>

However, cam length is only one element of cam design, and the effect of increasing stamp weight can also be seen on the robustness of cams (Figures 216 to 219). Light stamps were typically lifted by light and thin cam arms (Figure 216), while heavy stamps were lifted by cams with strengthening webs and extra reinforcing (Figure 218). However, again there are exceptions to these rules, and the lightweight Union Iron Works prospectors’ mills (Thames School of Mines and Canvastown monument) both have very robust cams for their lightweight (255 lb) stamps (Figure 219).

Figure 216. Lightweight cam from the Arethusa Battery, Longwood Range (site D46/161).
Figure 217. Typical mid-size cam with plain arms, at the Alpine Battery (site F24/265).

Figure 218. Heavy cams with strengthening webs at the Homeward Bound Battery (site F41/477).

Figure 219. A robust but short throw cam in the Union Iron Work’s prospectors’ battery at the Coromandel School of Mines.

The accuracy of the cam curve is difficult to assess in the field. Photographs of several cams were overlain over drawings of involute curves, and this exercise indicated that in general appropriate curves were being used, although a few mills did have unusual curves, including the Arethusa (site D46/161) with its very long arms (Figure 216).

One common factor that affected the cam curve was wear (Figure 220). Cams were prone to wear due to their constant striking and sliding contact with the tappets, and examples of cams
in every state from virtually as-new and unworn to severely worn and misshapen were recorded. The most extreme observed example of this is at the Young Australian Battery (site F42/25), where the worn cams have had new faces riveted on, producing extremely ‘lumpy’ cam curves (Figure 221).

![Figure 220. Worn cam at the Albion Battery (site Q27/112), Terawhiti. The wear is greatest at the point where the cam struck the tappet.]

![Figure 221. Two cams with repairs riveted to their faces at the Young Australian Battery (site F42/25) in the Carrick Range.]

**Lateral Thrust**

The management of lateral thrust from the cams was undertaken either by mixing left and right-hand cams, or by using collars next to the camshaft bearings. The majority of the archaeological examples (37 mills) had all the same cams and therefore relied on collars. There was a significant smaller group (10 mills) that used mixed left and right hand stamps (Table 38). There were also 2 mills that had one odd cam, which is probably simply evidence of replacement with mismatched spares. The mills fitted with mixed cams fell into three groups; mixed cams in one group on a camshaft (Figure 222); opposite-handed groups of cams on a single camshaft; and opposite-handed sets of cams on each camshaft in 2-shaft mills.
Table 38. Stamp mills with mixed cams to control lateral thrust. L=left hand cams, R=right hand cams.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Cams</th>
<th>Camshaft 1</th>
<th>Camshaft 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>L31/27</td>
<td>5</td>
<td>3L, 2R</td>
<td></td>
</tr>
<tr>
<td>Canvastown</td>
<td></td>
<td>2</td>
<td>1L, 1R</td>
<td></td>
</tr>
<tr>
<td>Four in Hand (Coro. Sch. Mines)</td>
<td></td>
<td>2</td>
<td>1L, 1R</td>
<td></td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>2</td>
<td>1L, 1R</td>
<td></td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>E41/477</td>
<td>10</td>
<td>5L, 5R</td>
<td>5R</td>
</tr>
<tr>
<td>Mayclair Coll.</td>
<td>Unknown</td>
<td>10</td>
<td>5L, 5R</td>
<td></td>
</tr>
<tr>
<td>Morning Star</td>
<td>B46/49</td>
<td>10</td>
<td>5L, 5R</td>
<td></td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>2</td>
<td>1L, 1R</td>
<td></td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>20</td>
<td>10L</td>
<td>10R</td>
</tr>
<tr>
<td>Waihi Museum</td>
<td>Unknown</td>
<td>10</td>
<td>5L, 5R</td>
<td></td>
</tr>
</tbody>
</table>

Figure 222. The camshaft at the A1 Battery (site L31/27). A mixture of left hand and right hand cams are used in the same 5 cam group.

Figure 223. The camshaft of the Eureka Battery (site E41/51) at Skippers. One left and one right hand cam are used.

It is notable that the use of mixed cams is particularly found within two very distinct groups of mills: the 2 stamp mills manufactured by Joshua Hendy or the Union Iron Works, both of San Francisco (Figure 223); and the large and heavy mills (Homeward Bound and Taitapu) manufactured by the Sandycroft Foundry and Fraser & Chalmers, both of England. The control of lateral thrust in this manner therefore seems to be something that New Zealand and Australian manufacturers of mid-weight mills often did not concern
themselves with. Locally-made heavy-weight mills, such as the A.&G. Price-made Bendigo (site T13/90) are too fragmentary to draw any conclusions.

**Cam Mounts**

Three forms of cam mount were identified in the archaeological survey; the standard key and keyway (Figure 224); the Blanton-type wedge (Figure 225); and the unique two-piece bolt-together cams on the Frasers Gully Battery (site I44/517). The conventional key and keyway was by far the most common form of cam fixture, with 54 examples recorded. In some cases double-sets of keys were used for extra security. The Blanton cam was found on 10 sites (Table 39), which all post-date the 1893 patent date of this design.

![Figure 224. A cam secured by a conventional key in a keyway on the Come in Time Battery at Bendigo (site G41/251).](image)

![Figure 225. A Blanton cam at the Eureka Battery, Skippers (site E41/51).](image)
Table 39. Stamp mills in which the Blanton-type cam was used.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Manufacturer</th>
<th>Date of manufacture</th>
<th>Cam size (inches)</th>
<th>Camshaft dia (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td>A&amp;G Price, NZ</td>
<td>1896</td>
<td>30</td>
<td>5 ½</td>
</tr>
<tr>
<td>Cherry &amp; Sons</td>
<td>T13/294</td>
<td>Fraser &amp; Chalmers, England</td>
<td></td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>Joshua Hendy, USA</td>
<td></td>
<td>26 ½</td>
<td>4 7/16</td>
</tr>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Allis-Chalmers, USA</td>
<td>1911</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Victoria</td>
<td>T13/300</td>
<td></td>
<td>(Broken)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex Roberts Bros.</td>
<td>Ex</td>
<td>‘BPS’</td>
<td>31</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>(at Hauraki P.A.)</td>
<td>T12/704</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>Sandycroft/ Fraser &amp; Chalmers, England*</td>
<td>1899</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>Snowy River</td>
<td>L31/37</td>
<td></td>
<td>30 ½</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>Fraser &amp; Chalmers, England</td>
<td>1896</td>
<td>31 ½</td>
<td>5</td>
</tr>
<tr>
<td>Ex Iris (at Opitonui)</td>
<td>Ex</td>
<td></td>
<td>26 5/16</td>
<td>4 5/16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T11/625</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The Homeward Bound machinery was manufactured by the Sandycroft Foundry, except for the cams which are embossed ‘F&C Ltd,’ see Figure 218 above. The camshaft itself is stamped ‘Sandycroft.’

Although the numbers of Blanton cam equipped mills was relatively low, this still represents a significant uptake of the design when its late date of 1893 is taken into account. The Blanton mount was most widely used in the more robust mills (ie with camshaft diameters of 5 to 6 inches) that were imported from America and Britain. However, the identification of Blanton cams manufactured by A&G Price at the Bendigo Battery proves that the design was also consciously adopted in New Zealand rather than simply being present on imported items.

Drop Order

The drop order used varied greatly (see Appendix B), but one particular drop pattern was commonly adopted; 1,4,2,5,3 and its reciprocal 1,3,5,2,4. These were used in 17 mills, including the large and well-engineered Homeward Bound (site F41/477) and Taitapu (site M25/86) mills, the operational Callery’s (site I42/161), as well as a number of what could be considered ‘standard mid-weight’ mills such as the Alpine (site F42/265), Britannia (site L29/15) and one bank of the Serpentine (site H42/2). This was the drop order that was considered to be the most common in the contemporary literature (see Table 8 in Chapter 5), and is known to have been used widely in New Zealand, Africa and the USA. It is the pattern defined by White (2010: 69) as the ‘Reverse Homestake’ and the ‘Homestake.’

The ‘California’ pattern of 1,4,2,3,5 that White (2010: 68-69) found to be most popular in that State was only represented by 4 mills, and three of them had different orders on each bank of 5 cams. It is therefore present but not common in the New Zealand archaeological record.

In 8 mills pairs of stamps were dropped at the same time, in contradiction to some of the contemporary sources, including New Zealand’s own Gordon (1906: 313). The most common pattern (7 mills) was to drop stamps 1 & 5 and 2 & 4 as pairs, with 3 dropped alone. This created the orders (1,5)3(2,4) or (1,5)(2,4)3. Adjacent stamps were not dropped together, so
the intention appears to have been to create a large but spread splash within the mortar box. With respect to the Golden Lead Battery (site L31/29) Staton’s research found that the deep mortar boxes coupled with the soft nature of the ore reduced the efficiency of the mill, and the doubling of the drops may have been a way of increasing the splash in order to get more material flowing through the screens (J. Staton, Dept. of Conservation, pers. comm. 2013). The use of a technique that was clearly contrary to the contemporary literature is notable, and was clearly very deliberate in all of the identified cases.

32 Jim Staton (Department of Conservation) has also suggested that dropping adjacent stamps would have been avoided as it would have been likely to fracture the mortar box.
Group 4: The Stamps

The stamp consists of four main sections: the stem, tappet, head and shoe; and each item can be discussed separately (see below), but the total weight of the entire assembly was also an important consideration. The stamp weight affected the required robustness of other parts of the mill, particularly the camshaft and cams, and it would be reasonable to assume that the weight would also affect the design of the stamp. To assess the archaeological evidence for this, the weights of the sample of 16 stamps that were calculated from the field evidence were compared to the types of tappet, stem diameters and stamp head diameters that were used (Table 40).

Table 40. Calculated stamp weights and details of main stamp components for 16 New Zealand stamp mills.

Stem (upper) measurements are only given for stems with screw-type tappets that have a reduced upper diameter. Date (a) is the date of manufacture, and Date (b) is the date of erection at last place of work.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Weight (pounds)</th>
<th>Stem dia (upper) (inches)</th>
<th>Stem dia (lower) (inches)</th>
<th>Stem length* (inches)</th>
<th>Tappet</th>
<th>Head dia. (inches)</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex Roberts Bros. (Hauraki P.A.)</td>
<td>Ex T12/704</td>
<td>1240</td>
<td>3 11/16</td>
<td>187 ¾</td>
<td>Gib</td>
<td>9</td>
<td>After 1896</td>
<td>1950s?</td>
<td></td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>1120</td>
<td>3 ½</td>
<td>184</td>
<td>Gib</td>
<td>9</td>
<td>1899</td>
<td>1910</td>
<td></td>
</tr>
<tr>
<td>Govt. Coromandel</td>
<td>T10/1115</td>
<td>1030</td>
<td>3 ½</td>
<td>187 ¾</td>
<td>Gib</td>
<td>9</td>
<td>1899</td>
<td>1899</td>
<td></td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td>840</td>
<td>3 ¼</td>
<td>150 ½</td>
<td>Gib</td>
<td>10</td>
<td>1900, 1902</td>
<td>1900, 1902</td>
<td></td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>830</td>
<td>3 ¼</td>
<td>163</td>
<td>Gib</td>
<td>8 ½</td>
<td>1903</td>
<td>1897</td>
<td></td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>780</td>
<td>3 7/16</td>
<td>127</td>
<td>Gib</td>
<td>8 ½</td>
<td>1905</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex Iris (at Opitonui)</td>
<td>Ex T11/625</td>
<td>740</td>
<td>3 1/16</td>
<td>164</td>
<td>Gib</td>
<td>8 ¼</td>
<td>1926</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>720</td>
<td>3 1/4</td>
<td>137</td>
<td>Gib</td>
<td>8</td>
<td>1903</td>
<td>1903</td>
<td></td>
</tr>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>685</td>
<td>2 3/8</td>
<td>3</td>
<td>114 ¾</td>
<td>Screw</td>
<td>10</td>
<td>1882</td>
<td></td>
</tr>
<tr>
<td>No. 2 South Larry’s</td>
<td>L30/7</td>
<td>670</td>
<td>2 7/8</td>
<td>113 ½</td>
<td>Collar</td>
<td>10</td>
<td>Ca 1874</td>
<td>1892</td>
<td></td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/25</td>
<td>565</td>
<td>2 7/8</td>
<td>103 ½</td>
<td>Collar</td>
<td>8 ½</td>
<td>1871</td>
<td>1896</td>
<td></td>
</tr>
<tr>
<td>Canton</td>
<td>H44/831</td>
<td>490</td>
<td>2 3/8</td>
<td>2 7/8</td>
<td>104</td>
<td>Screw</td>
<td>9 ¼</td>
<td>1910</td>
<td></td>
</tr>
<tr>
<td>Albion</td>
<td>Q27/112</td>
<td>480</td>
<td>1 7/8</td>
<td>2 7/8</td>
<td>113.5</td>
<td>Screw</td>
<td>8 3/4</td>
<td>1882</td>
<td></td>
</tr>
<tr>
<td>Ex Moewai (Mercury Bay Museum)</td>
<td>D46/161</td>
<td>415</td>
<td>1 7/8</td>
<td>2 9/16</td>
<td>112</td>
<td>Screw</td>
<td>8 ¼</td>
<td>1908</td>
<td></td>
</tr>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>400</td>
<td>2 3/8</td>
<td>2 7/8</td>
<td>101 ½</td>
<td>Screw</td>
<td>8 5/8</td>
<td>1887</td>
<td></td>
</tr>
<tr>
<td>Ex Four-in-Hand (Coro. Sch. Mines)</td>
<td></td>
<td>255</td>
<td>2 ½</td>
<td>84 ½</td>
<td>Gib</td>
<td>6</td>
<td></td>
<td>1930s</td>
<td></td>
</tr>
</tbody>
</table>

*Note that the measured stem length in all cases excludes the 4 to 6 inch section that is inserted into the stamp head.
As this sample shows, there was a strong direct correlation between stamp weight and the choice of tappet design, with screw tappets only found on lighter stamps, and all of the heaviest stamps were fitted with gib tappets. The relationship between stamp weight and stamp head diameter was less straightforward, with the heaviest stamps all having 9 inch diameter heads, while some mid-weight stamps had larger 10 inch heads. This issue is discussed further below (under *The Head*). There also appears to be a correlation between the date of manufacture and the stamp weight, with heavy stamps becoming more common over time, a trend that was commented on by contemporary authors (see Chapter 5). The relationships between weight, date of manufacture and tappet type are therefore all inter-related, with the improved form of the gib tappet becoming more widespread at the same time that stamp weights were increasing.

**The Stem**

The usual form of the stem is a straight-sided iron rod between 2 inches and 3 11/16 inches diameter, and between 84 1/2 inches and 187 3/4 inches long, the dimensions being generally (but not absolutely) proportional to stamp weight (Table 40). Variations in the design of stamp stems are mainly concerned the provision for tappet mounting in the case of screw tappets and the provision for stamp head mounting at one or both ends.

Tappet mounting was only a specific stamp stem design issue for screw mounted tappets, when a thread would need to be cut for the tappet to be mounted. This threaded section is typically from 16 to 18 inches long to allow for tappet adjustment.

The stem mount into the stamp head was by a taper on the end of the shaft, and a matching bore in the head. The stem could be tapered on both ends to allow it to be turned over if it broke (which usually happened at the head). One unusual form is on the ex-Burnt Creek Mill (site H45/39) now on display in Lawrence that has short threaded section on the tops of most stems, although the purpose of this is not known.

**Tappets**

Examples of the 3 main varieties of tappet design were found, these being the simple collar tappet (Figure 226), the screw tappet (Figure 227) and the gib tappet (Figure 229). A two-piece bolt-together tappet was found only at the small Fraser’s Gully Battery (site I44/517). The first detailed historical record of tappet design in the Otago goldfields is that of the ten stamp OPQ battery of 1864, which was equipped with “a screw or thread, and key nut whereby to fix the discs instead of the old manner of having them keyed on to the stalk” (*Otago Witness*, 18 June 1864: 16). Despite this contemporary report clearly stating that the key-type (or collar) tappet was out of date and had been replaced by the screw tappet by the 1860s, the collar tappet was commonly found, with 18 mills being so equipped (of which 3 had a mixture of tappet types).
There is a correlation between date of manufacture and stamp weight with the use of collar tappets. For all of the mills of known age with them, the youngest is the Golden Lead (site B46/41) that was possibly manufactured in 1886, and the key type tappet was not used on heavy mills (over about 700lb stamps). The tappets with the most extensive wear found during the archaeological survey, those on the Young Australian (site F42/25), were collar tappets.

The screw-type tappet was recorded in 24 mills. These were all fitted with a key to lock them in place rather than a second lock-nut. As discussed in Chapter 5 the screw tappet was considered out of date in America by the 1870s due to its propensity to work loose and wear rapidly, but that several authors observed that its use continued for a long time in ‘colonial’ (Australian) practice. Both of these observations are supported to a degree by the New Zealand archaeological evidence; thread wear was an issue (although not to the degree expected), and use of the screw tappet continued here well in to the twentieth century.

Figure 227 shows an almost unworn tappet at the Come in Time battery (site G41/251) that was built in 1908 using second-hand parts from a mill that had done a great deal of work. A number of new parts must have been incorporated into the rebuild, including these stamp stems and tappets that were by 1908 very out of date. Figure 228 shows a very worn screw tappet at Anderson’s battery (site F41/473), which exhibits the thread wear that was often attributed to this design. However, most observed examples did not exhibit wear to this extent, and were still serviceable.
The preferred form of tappet by the late nineteenth century was the Californian gib tappet, and the New Zealand archaeological evidence agrees with this. Twenty-six mills were recorded that use this type of tappet, and spare gib tappet-equipped stamp rods were stockpiled at the screw-tappet equipped Anderson’s Battery (site F41/473) (Figure 229). All of the very heavy and known late-date mills are equipped with this form of tappet.

The Stamp Head

Stamp head diameters varied between 6 and 10 inches (with most between 8 and 9 inches), while lengths varied between 11 and 24 inches (with most between 12 and 17 inches). It is of note that the widest heads (10 inches) were typically 14 inches long and were found on mid-weight stamps (700-800 lb), while the longest (19 to 24 inches) and heaviest (1000 lb+) heads were typically about 9 inches diameter (see Table 40). This fits with the contemporary practice described in Chapter 5 that crushing pressure was determined by stamp diameter, with 9 inch heads often being used on 1000+lb stamps (eg Louis 1902: 181).
Also as described in Chapter 5, all stamp heads had two slots through the body at right angles to each other (Figure 230), one for driving out the stamp stem from the top; and one for driving out the shoe at the bottom. A number of heads have had iron bands placed around their top and/or bottom, in some cases to strengthen the head, and in other cases to repair fractured heads. Again, this corresponds with the contemporary literature.

Figure 230. A stamp head from the Arethusa battery (site D46/161). This is a relatively light stamp, the overall weight being 400 lb.

The Shoe

The shoe was mounted on the base of the stamp head, and along with the die was actually in contact with the ore and consequently wore rapidly. It was therefore a service item, designed to be replaced regularly, and the archaeological evidence supports this with heavily worn, lightly worn and brand new shoes all recorded during the survey (Figures 231 and 232).

Figure 231. Discarded worn out shoe with square shank at the Alta Battery, Bendigo (site G41/253).

Figure 232. Unused shoe with round shank at the Alta Battery, Bendigo.

Stamp shoes were a similar diameter to the stamp to which they were fitted, usually within ½ inch larger or smaller. The length varied widely, the shortest worn out example being ¾ inch long (at the Premier/Maryborough, site F41/471), while examples of unused shoes were
typically between 7 ¼ inches and 10 inches long. The longest shoes recorded were the 12 ¼ inch examples fitted to the Roberts Brothers’ stamps held by the Hauraki Prospectors’ Association in Thames (Figure 233). These stamps were the heaviest recorded, at 1240lb, and clearly the shoes were designed to substantially contribute to this weight. If, as already discussed, these stamps did originate in the Victoria Battery at Waikino (site T13/300), this calculated weight agrees almost exactly with the historically-reported reported 1250lb stamps.

Figure 233. Stamp heads and shoes from the Roberts Brothers’ Battery, now held by the Hauraki Prospectors’ Association in Thames.

The Dies

The dies were also service parts that wore rapidly and were regularly replaced, and in common with shoes both worn and unworn examples were recorded (Figure 234). Most recorded dies consist of a round upper section on a hexagonal or square base. The diameter of the die was typically between 8 and 9 ½ inches, and the base was usually ¼ to ¾ inch larger. The range of measured heights of die was not as great as shoes, and they ranged from 6 inch high unused items (Figure 234) down to those that had been worn to the level of their base, which was 1 ¼ inch in the case of one die at the Big River Battery (site L31/4).

Figure 234. Unused and slightly used dies at the Taitapu Battery (site M25/86) in NW Nelson.

One of the distinguishing features of the California Stamper was the rotation of the stamps in order to even out the wear on the tappets, shoes and dies. Many of the used dies that were recorded were reasonably evenly worn, indicating that the battery was operating correctly. However, some examples of extremely
uneven wear were observed, such at the Snowy River Battery (site L31/37) at Waiuta where one discarded die had a variation in height of nearly 4 inches (Figure 235). It seems likely that the stamp shoe and die both wore unevenly and got ‘locked’ in position, with the stamp failing to rotate as it worked. Other shoes and dies at the site showed even wear, indicating that the problem was limited to possibly just one stamp.

Figure 235. A very unevenly worn die at the Snowy River Battery (site L31/37) near Waiuta.
Chapter 9
The Archaeological Evidence: The Milling Circuit & The Complete Mill

The stamp mill was only one stage in the milling circuit, albeit the most archaeologically enduring. Each battery was equipped with slightly different combinations of the additional plant discussed in Chapter 6, which could vary widely depending on a number of variables, including the size of the mill, the capital available and the geological nature of the ore. As already discussed, no batteries of more than 20 stamps survive, so the milling circuits of New Zealand’s largest plants can only be interpreted through historical sources, fragmentary foundation remains, and comparison with smaller mills that retain more comprehensive evidence of additional processing plant. As a consequence, the best-preserved sites such as Callery’s battery (site I42/161) and the Lillis Battery (site T10/773) are discussed at length in this Chapter (despite the Lillis not being a stamp mill, but rather a ball mill battery), as they provide evidence of the more fragile features that have disappeared from more ruinous sites.

Pre-Treatment

Ore & Concentrate Roasting

Kiln and furnace designs recorded in the survey (Table 41) included reverberatory and rotary forms in above-ground structures, and a number of in-ground vertical kilns similar in operation to lime kilns. In addition to these, Moore & Ritchie (1998) recorded another 6 examples of the in-ground type, which were not revisited.

Table 41. Ore and concentrate kilns and furnaces recorded during the archaeological survey.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Furnace type</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexander</td>
<td>L31/83</td>
<td>Edwards Roaster</td>
<td>1934</td>
<td>Intact</td>
</tr>
<tr>
<td>Snowy River</td>
<td>L31/37</td>
<td>Edwards Roaster</td>
<td>1924</td>
<td>Foundations only</td>
</tr>
<tr>
<td>Ferguson’s New Era</td>
<td>T13/104</td>
<td>Roasting furnace</td>
<td>1899</td>
<td>Base brickwork survives</td>
</tr>
<tr>
<td>Prohibition Mill</td>
<td>L31/47</td>
<td>Edwards Roaster</td>
<td>1938</td>
<td>Foundations only</td>
</tr>
<tr>
<td>Tipperary</td>
<td>F41/485</td>
<td>Reverberatory roasting furnace</td>
<td>1896</td>
<td>Largely intact</td>
</tr>
<tr>
<td>Kapai/Vermont</td>
<td>T10/1034</td>
<td>In-ground kilns</td>
<td>1894-6</td>
<td>3 partly intact</td>
</tr>
<tr>
<td>Victoria</td>
<td>T13/300</td>
<td>In-ground kilns</td>
<td>1897 or 1898</td>
<td>Intact</td>
</tr>
<tr>
<td>Whangamata</td>
<td>T12/601</td>
<td>Rotary furnaces</td>
<td>1899</td>
<td>Fireboxes and flues remain</td>
</tr>
<tr>
<td>Woodstock</td>
<td>T13/356</td>
<td>In-ground kilns</td>
<td>1894-95</td>
<td>Largely intact</td>
</tr>
</tbody>
</table>

Concentrate roasting was not a pre-treatment, but is included here with the other furnace treatments for simplicity.
Well-preserved furnace and kiln remains are the 1896 Tipperary ore furnace (Figure 236), the 1897/98 in-ground kilns at the Victoria Battery (Figure 237), 1899 Whangamata Gold Corporation rotary kiln brickwork (Figure 238) and the 1934 Edwards Roaster at the Alexander Mine (Figure 239).

Figure 236. The 1896 furnace and site of the stamp mill at the Tipperary Battery (site F41/485) in 1993. Floods have subsequently covered the battery site in gravel, but the furnace still stands.

Figure 237. One of the in-ground ore roasting kilns at the Victoria Battery (site T13/300).

Figure 238. The brickwork dustchamber and flue for the two rotary furnaces at the Whangamata Gold Corporation Battery (site T12/601).
Most of this archaeological evidence for ore roasting dates to the 1890s, as Moore & Ritchie (1998: 57) also concluded, with a 1920s/1930s adoption of reverberatory furnaces as part of the milling circuit after initial crushing. Moore & Ritchie (1998: 57) found no immediate Australian precedent in the use of ore kilns in the 1890s, but concluded that the main influence was American, and that the early roasting practices were abandoned once wet crushing and cyanide treatment became widespread.

The subsequent use of reverberatory furnaces was an attempt to increase further gold recovery from concentrates, although it met with mixed results, and the best preserved furnace, the Alexander Mine Edwards Roaster, was only in use for a year (AJHR 1936 C2: 24, 35).
Preliminary Sizing

Preliminary sizing was carried out using grizzlies to screen the ore, and rock breakers to reduce any lumps that were too large to feed to the stamps. Only 2 in situ grizzlies and 5 rock breakers (Table 42) were recorded, although many mills would have been equipped with both.

Table 42. Rock breakers recorded in association with battery sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA no.</th>
<th>Type</th>
<th>Maker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callery’s</td>
<td>I42/161</td>
<td>Jaw crusher</td>
<td>Parke &amp; Lacy, San Francisco</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>Jaw crusher</td>
<td>P.G. &amp; Co.</td>
</tr>
<tr>
<td>Lillis</td>
<td>T10/773</td>
<td>Jaw crusher</td>
<td>Ross</td>
</tr>
<tr>
<td>Lillis</td>
<td>T10/773</td>
<td>Gyratory crusher</td>
<td></td>
</tr>
<tr>
<td>Phoenix</td>
<td>E40/40</td>
<td>Jaw crusher</td>
<td>Kincaid &amp; McQueen, Dunedin</td>
</tr>
<tr>
<td>Talisman</td>
<td>T13/286</td>
<td>Jaw crusher</td>
<td></td>
</tr>
</tbody>
</table>

The best example of a grizzly is at Callery’s Battery (site I42/161) (Figure 240). This is in the chute running down from the ore bin, with the bars set between 1 ½ and 2 inches (probably originally a nominal 1 ½ inches) apart. Anything that did not pass through the grizzly could then be broken in the 8 inch jaw ‘Dodge Rockbreaker’ that was manufactured by Parke & Lacy of San Francisco. A smaller grizzly at the Lillis Battery (site T10/773) (Figure 241) fed into a small Ross jaw crusher. The same mill was also equipped with a small gyratory crusher, but the structure that held both machines has recently collapsed. The Kincaid & McQueen rock breaker that is still in situ above the Phoenix/Achilles Battery is an example of a New Zealand manufactured machine (Figure 242).

Figure 240. The ore bin, grizzly and jaw crusher at Callery’s Battery (site I42/161). The steps are a modern addition.

Jaw crushers were as mobile as most other forms of battery equipment, and the lack of surviving samples is probably due to them being removed from closed mills for reuse. It is notable that several otherwise largely complete mills, such as the Taitapu (site M25/86), are missing their rock breakers.
Figur 241. The grizzly and small Ross jaw crusher at the Lillis Battery (site T10/773) in about 1996.

Figure 242. The Kincaid & McQueen Co. Ltd. jaw crusher at the Phoenix/Achilles Battery (site E40/40).

Ore Feeders

There is good archaeological evidence that ore feeders were widely used. Despite being relatively lightweight and portable, a number of feeders have survived, either whole or in parts. The best in situ examples are the operational feeder at Callery’s battery (site I42/161) (Figure 243) and the two intact feeders at the Homeward Bound Battery (site F41/477) (Figure 244). The Big River Battery (site L31/4) has the frame for one feeder in place, the other one having been removed to the Black’s Point Museum. Distinctive feeder parts were observed at the Bendigo (site T13/90) (Figure 245), Inglewood (site L30/175) and Golden Blocks (site M25/81) batteries. Feeder parts at the Britannia Battery (site L29/15) are embossed ‘Challenge Ore Feeder,’ together with the manufacturers’ name ‘Parke & Lacy Co. Ltd., Sydney.’

Figure 243. The ore feeder at Callery’s Battery (site I42/161).
Figure 244. One of the two Challenge ore feeders at the Homeward Bound Battery (site F41/477).

Figure 245. The discs from two Challenger ore feeders amongst debris at the Bendigo Battery, Waiorongomai (site T13/90).
The Crushing/Grinding Stage

The majority of archaeological remains of gold ore processing plants are stamp mills, but a significant minority of sites include evidence of other crushing or grinding machinery, either as an additional process in the milling circuit, or to replace stamps. The most common item is the Berdan, but other machines also survive in low numbers.

Centrifugal Roller Mills: The Huntington Mill

The Huntington mill was used in the place of stamps in a number of mills, particularly in East Otago in the Nenthorn and Macraes areas. There are no known Huntington Mills still on their last work site, but the largely complete 3 ft. 6 in. mill from the Bonanza Mine is now at the Golden Point Reserve (Figures 246 & 247), where it has been erected for display along with its associated grinding pan, Pelton wheel and layshaft in replica timber frames. Embossed on the side of the mill is ‘F.A. Huntington Centrifugal Roller Quartz Mill, Parke & Lacy, Patentees, Sydney, N.S.W.’ When first erected in 1889 it was powered by a steam engine, but when the mill was moved in 1894 the Pelton wheel was installed (AJHR 1895 C3: 88).

Figure 246. The re-erected Bonanza at the Golden Point Reserve in Otago. The Pelton wheel and Prices’ grinding pan is on the left, and the Huntington Mill on the right.

Figure 247. The Huntington Mill from the Bonanza Mine at Nenthorn.
The Berdan

The Berdan is the most common form of grinding pan found in the New Zealand goldfields, with 57 individual pans being recorded (many others are held by museums). It was widely used as a secondary ore grinding and amalgamating stage, after initial crushing by stamps or other mills. Berdans were often used in multiples, with 13 sites having single Berdans, 12 sites having 2 Berdans, and 4 sites each having 3, 4, 6 and 7 Berdans. They vary in size from 43 inches outside diameter (Printz’s Battery, site D46/150) to 60 inches diameter (Garden Gully, site K31/51; Kirwan’s Reward, site L30/62; and United Goldfields, site F41/484). Only a few Berdans bear makers’ names, and the observed examples were all manufactured by A.&G. Price of Thames.

Most exposed examples of the timber support frames have decayed away, although some have survived in the arid conditions of Central Otago (Figure 248), and the Lillis Battery (site T10/773) has two Berdans intact and under cover (Figure 250). The set of 7 Berdans at the Invincible Battery (site E40/58) (Figure 251) that were installed in 1886 was retimbered by the Department of Conservation in 2001 (Otago Daily Times, 11 May 2001).

Figure 248. The Berdan at Anderson’s Battery (site F41/473) in the 1970s (Lakes District Museum, EL0588).

Figure 249. The Anderson’s Battery Berdan frame, from measurements taken in 2010.
The archaeological evidence indicates the widespread use of the Berdan in New Zealand. This runs counter to the comment made by H.A. Gordon in 1906 (p. 415) that they were crude appliances and their use likely to be discontinued. Although some of the recorded sites pre-date his comments, others (such as Anderson’s and Lillis batteries) were erected later. It is of particular note that the Government Battery in Coromandel (site T10/1115) was built in 1899/1900 with a set of Berdans, and it would be expected that being a Mines Department project it would reflect current standard practice. It is likely that the simplicity and effectiveness of the Berdan ensured its widespread adoption and continued use in New Zealand.
Other Grinding Pans

McKay & Watson-Denny Pans

The best archaeological evidence for the use of grinding pan plants is the 1888 Maratoto Gold-mining Company’s pan amalgamation plant (site T13/276) beside McBrinn’s Creek. The site is now the only intact in-situ pan amalgamation plant known in New Zealand, and consists of two McKay pans (Figure 252), a separating pan (Figure 253) and the boiler that was used for producing steam to heat the pulp in the pans (see Chapter 6 for an account of the process).

Figure 252. The Maratoto Gold-mining Company’s pan amalgamation plant (site T13/276) in 2011. In the foreground and right background are two McKay’s grinding and amalgamating pans, and between then is a separating pan.

Figure 253. The distinctive outlets of the separating pan at the Maratoto Gold-mining Company’s pan amalgamation plant.
Evidence of other pan grinding and amalgamation plants is more fragmentary and displaced. A muller from a McKay pan survives at the Woodstock Battery (site T13/289) (Figure 254), and the Bonanza battery on display at the Golden Point Reserve (Figure 246 above) includes a 5 feet 11 inch diameter grinding pan. The Hauraki Prospectors’ Association collection in Thames contains several unprovenanced Watson & Denny pans manufactured by Chas. Judd of Thames (Figure 255). This was an Australian design, by Thomas Watson of St. Arnaud and Thomas Denny of South Yarra, and operated in a similar fashion to the McKay pan (AJHR 1889 C3: 21). The surviving evidence is therefore that a number of different designs of grinding pan were in use in New Zealand, and that many of them were manufactured under licence by A.&G. Price or Charles Judd, both of Thames.

**Figure 254.** The muller (rotor) from a McKay pan at the Woodstock Battery (site T13/289).

**Figure 255.** Watson & Denny patent pan manufactured by Chas. Judd of Thames. In the collection of the Hauraki Prospectors’ Association in Thames.
Ashcroft’s Crusher

The Ashcroft’s Crusher at the Phoenix Mine (site Q27/114) is a grinding pan that was a development of the Berdan, the main difference being that the iron pan was stationary and a pair of iron balls were pushed around by a central shaft (Figure 256). The Ashcroft’s Crusher is unusual in that it was designed, patented and manufactured in New Zealand. Only two examples are known to have been made in 1882 (Brodie 1986: 146-147) and this is the only survivor. While a design dead-end, it does show that attempts at local innovation were being made in the New Zealand goldfields.

Figure 256. The Ashcroft’s Crusher at the Phoenix Mill (site Q27/114) in 2011.

Ball & Tube Mills

The ball and tube mills that supplemented and then replaced the standard stamp mill have survived in the archaeological record in very low numbers, possibly because they were relatively modern and could be recycled into other industries, and because the later mill sites tended to have good road access allowing easier access for scrap removal. Only one tube mill is known to survive from those that were installed at the Victoria Battery (site T13/300) between 1903 and 1908 (McAra 1988: 140, 142, 336). It was purchased by the Roberts brothers when the Victoria Battery closed for their mill in Thames (site T12/704), and later returned to Waikino by the Department of Conservation (N. Ritchie, pers. comm. 2013). It has been cut down to only half of its original length (Figure 257).

Figure 257. The modified tube mill at the Victoria Battery (site T13/300) in 2012.

A number of small ball mills exist, at the Lillis Battery (site T10/773), the Coromandel Government Battery (site T10/1115) and an unmounted example in the Hauraki Prospectors’
Association collection in Thames. All three are examples of conical mills, where the output end of the mill is cone-shaped. The Lillis ball mill was photographed in 1996 and in 2010, during which time it had deteriorated significantly (Figures 258 & 259). The Lillis Battery was built in 1956, and is an example of a late small-scale mill where the stamps had been superseded.

Figure 258. The ball mill at the Lillis Battery (site T10/773) in 1996.

Figure 259. The Lillis ball mill in 2010. By this date the lining had been removed (through a hole cut in the far side of the housing), and the drive shaft had been removed. The timber frame has since collapsed.
Post-Crushing Ore Treatment

As discussed in Chapter 6 above, gold saving (particularly by amalgamation) was often partially undertaken during the crushing and grinding stages, and the Berdans and other grinding pans discussed above were often used as gold saving appliances as well as ore reducers. The plant described below had no further role in reducing the ore size, but was solely concerned with classifying, concentrating and gold recovery.

Battery Tables

The simplest form of gravity separation was the blanket or riffle table set in front of the stamp mill. A number of wooden tables survive, but it is often difficult to determine whether a table was a gravity table (equipped with strakes/riffles or blankets) or an amalgamating table (equipped with copper plates), as almost invariably only parts of the heavy timber structure remain. In many cases it is known from historical records that both blankets and amalgamating plates were used together at a single site. For this reason, the archaeological evidence of all tables is considered together.

Only one definitely identifiable intact riffle table survives, at the Lillis Battery (site T10/773). The table is constructed using timber slats set across the run of the table (Figure 260), and was placed last in the milling circuit, to process tailings after the Berdans. It is of late (post-1956) construction.

Figure 260. The riffle tables at the Lillis Battery (site T10/773) in about 1996.

Two intact amalgamating tables survive with their copper alloy plates, at the Lillis Battery (site T10/773) and at Callery’s Battery (site I42/161). The Lillis table (Figure 261) is 6 feet 9 inches long and 3 feet 3 inches wide, and falls in three steps, with a heavy copper alloy plate screwed to each step (the plates are still on site, but are now loose). Like the associated riffle table, this amalgamating table is of post-1956 construction. The Callery’s amalgamating table (Figure 262) is in two parts; an upper section that is 57 inches wide and 37 inches long, with three steps; and it then narrows with the lower section being 37 ½ inches wide and 78 ½ inches long, with 5 shallow traps. Both parts are covered in a copper or copper alloy sheet. From the bottom of the table the pulp is taken by a launder to a Wilfley table. The Blacks Point Museum and Coromandel Government Battery are both equipped with tables, but both are modern rebuilds.
Figure 261. Amalgamating table at the Lillis Battery in 2010.

Figure 262. The amalgamating table at Callery’s Battery (site I41/161). In the foreground is the launder that runs to the Wilfley table.

Other examples of tables are more decayed and fragmented, with their copper alloy plates missing. The Alpha Battery in Preservation Inlet (site B46/42) (Figure 263) was equipped with copper plates that were reported to be 6 feet long and 11 feet wide, and blanket strakes that were 9 feet in length (AJHR 1903 C3: 114). The surviving tables are 5 feet 9 inches long and 5 feet 2 inches wide. These dimensions suggest that the contemporary figures included the full width of both tables, and that only the amalgamating tables have survived. There is now no visible evidence of the 9 feet long blanket strakes.

Figure 263. The 1899 Alpha Battery (site B46/42) in Fiordland in 2005.
The Homeward Bound Battery (site F41/477) also has surviving amalgam tables, albeit in poor condition, (Figure 264), together with associated cast iron mercury traps (Figure 265). The tables are 12 feet 10 inches long and 5 feet 1 inch across. An account of this battery in its original location at Waipori described it as having outside copper plates that were 12 feet long and 5 feet wide, *(New Zealand Mines Record*, 1899 Vol. III No. 4: 143), which agrees reasonably with the archaeological evidence.

![Figure 264. The tables at the Homeward Bound Battery (site F41/477) in 2010.](image)

![Figure 265. Mercury trap at the Homeward Bound Battery (site F41/477).](image)
The one intact table (Figure 266) at Anderson’s Battery (site F41/473) also has indications that it was used with mercury, as the top end of the table has the remains of what appear to be two mercury traps (Figure 267). This table is 10 feet 3 inches long and 5 feet 5 inches wide.

Figure 266. The surviving table at Anderson’s Battery (site F41/473) in 2010.

Figure 267. The remains of the traps at the head of the table at Anderson’s Battery.

A common feature of many batteries that appear to have had amalgamating tables is the presence of one or more Berdans, and several sites also have amalgamating barrels (see further discussion below). There therefore appears to be a strong correlation between the use of mercury elsewhere in the milling circuit and the use of amalgamating tables. A notable exception is Callery’s Battery (site 142/161) that has an amalgamating table followed by a Wilfley table, but this battery is also atypical in that it was used for scheelite as well as gold recovery.

The surviving archaeological evidence is therefore strongly weighted towards amalgamating tables rather than riffle/blanket tables, even on sites where blanket tables were known to have also been used.
Buddles

Buddles were used in a number of New Zealand mills, such as the Woodstock at Karangahake (Auckland Star, 20 April 1895: 5) and McGill’s Battery at Macraes (Otago Witness, 23 September 1903: 23), but the only substantial example to survive is the circular buddle built by the Otago Pyrites Saving Company in 1884 (Figure 268) (site E40/59) to treat the tailings from the Invincible Battery (site E40/58). The circular buddle (sometimes referred to as a rotating convex table or, mistakenly, as a Cornish buddle) is 26 feet in diameter, and was imported from Germany (Otago Witness, 27 August 1886: 12). The cast iron central column remains in place, but the sweeps are missing. The cement surface of the buddle was replaced in 1983.

Figure 268. The 1884 circular convex table (site E40/59) below the Invincible Mine.

Vanners & Shaking Tables

Despite the known historical popularity of the Frue Vanner and other similar moving-belt machines, little survives in the archaeological record other than a few parts, and no complete machines are known. The only physical evidence that was found was an unprovenanced vanner head unit in the collection of the Hauraki Prospectors’ Association (Figure 269), and a possible roller at the Woodstock Battery (site T13/289) reported by Ritchie (1990: 210).

Figure 269. Vanner head in the collection of the Hauraki Prospectors’ Association in Thames.
Shaking tables are also not well represented, with the notable exception of the Wilfley Table (see below). A small shaking table, probably of 1960s manufacture, is at the Lillis Battery (Figure 270) (site T10/773).

![Shaking Table](image)

**Figure 270. The portable shaking table at the Lillis Battery (site T10/773) in 2010.**

**The Wilfley Table**

The Wilfley Table is the best-represented shaking table in the archaeological record. Although Gordon (1906: 456) noted that in 1906 few Wilfley tables were in use in New Zealand, historical sources indicate that they later became widely used and this is supported by the archaeological evidence. There are however no surviving examples of the multiple-table arrangements that existed in some mills, such as the 7 tables at the Snowy River Battery (site L31/37) (Hancox 1985: 44).

Several operational individual examples survive, the table at Callery’s Battery (site I42/161) probably being the only one that is still in operational condition in its last working location (Figure 271). This table is 16 feet long and 6 feet wide. It is covered with brown linoleum and narrow timber riffles. The Hauraki Prospectors’ Association have an operational relocated table in their battery display that is regularly run. Parts of Wilfley tables are present at several sites. Most of the main hardware from a disassembled table survives at the Homeward Bound Battery (F41/477), including the iron frame for a 15 feet 10 inches long by 5 feet 11 inches wide table top (Figure 272), and the main base beam. A derelict Wilfley table of unknown provenance was observed at Barewood in Otago in 1996 (Figure 273).
Figure 271. The Wilfley Table at Callery’s Battery (site I42/161) in 2011.

Figure 272. The frame for the Wilfley Table at the Homeward Bound Battery (site F41/477) in 2011.
Mercury Amalgamation

There is ample archaeological evidence of the use of mercury in the historic gold milling industry. As already discussed, Huntington Mills, McKay Pans and Berdans were all amalgamating as well as grinding machines, and most surviving battery tables were probably amalgamating tables. Based on historic sources mercury amalgamation was the most commonly used gold-saving technique, and was the primary gold-saving method even if secondary processes such as cyanidation were employed. Archaeological investigations support this, as evidence of mercury has been found at several sites. Analysis of the battery fines in one cyanide tank of the Deep Dell Battery (site I42/15) in Otago found both gold and mercury present (Hamel 1994: 12), while metallic mercury was found at the nearby Golden Bar Battery (site I43/88) (Petchey 2005: 11). Both of these sites shared the same crushing machinery, which was moved from the former to the latter in 1927, but cyanide treatment was only used at the Deep Dell site. At Big River (site L31/4), where cyanide treatment was also used, Bill Watts of Blacks Point has reported panning mercury amalgam from the river bed downstream from the battery site (W. Watts. Pers. comm. 2011).

Various items of equipment that are solely associated with mercury amalgamation can also indicate its use. The mercury troughs associated with amalgamating tables have already been mentioned above (see Figure 265). The other evidence falls into two general categories; recovery of the amalgam, and processing of the amalgam to recover the gold.

Mercury amalgam was cleaned up and collected in several main appliances; the Berdan, amalgamating barrel and separating pan, the first and last of which have already been discussed above. Amalgamating barrels are present at 5 sites (Table 43), although none are still mounted. All are of similar design consisting of a sheet iron drum with an oval hatch, mounted on a spindle (Figure 274).
Table 43. Sizes and locations of amalgamating barrels.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Length (inches)</th>
<th>Diameter (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>37 1/8</td>
<td>26 1/4</td>
</tr>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>38</td>
<td>23</td>
</tr>
<tr>
<td>Serpentine</td>
<td>H42/2</td>
<td>37 1/2</td>
<td>26 1/4</td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/25</td>
<td>40 1/4</td>
<td>29 1/2</td>
</tr>
</tbody>
</table>

Figure 274. The amalgamating barrel at the Young Australian Battery (site F42/25).

The equipment that was used to process mercury amalgam once it had been scraped from the tables or collected in drums or pans includes mercury safes for collecting the amalgam, and retorts and furnaces for heating it. Two mercury safes were found, at the Golden Blocks (site M25/81) and nearby Taitapu (site M25/86) batteries (Figure 275). Both batteries are also equipped with Berdans (the Taitapu with 4, the Golden Blocks with a single example).

Figure 275. Mercury safe at the Taitapu Battery (site M25/86).

Parts of mercury retorts are found at many battery sites, including Fraser’s Gully (site I44/517) and the Premier/Maryborough (site F41/471) (Figures 276 and 277). At the Taitapu battery the remains of the nearby assay house (site M25/182) include the small brick furnace (Figure 278) that would have been used for assay work and retorting the amalgam.
Figure 276. Top of mercury retort at Fraser’s Gully Battery (site I44/517).

Figure 277. Bottom of mercury retort at the Premier/Maryborough Battery (site F41/471).

Figure 278. The furnace at the Taitapu assay house (site M25/182).
**The Cyanide Process**

The archaeological evidence for the use of the cyanide process is ample, usually in the form of cyanide vats. This is probably for several reasons; the cyanide process was a ‘late’ process, and more likely to survive archaeologically; and most cyanide vats were made from sheet iron or corrugated iron, neither of which has the attraction to the scrapman of large iron castings, and several battery sites that have been stripped of all heavy machinery still retain their iron cyanide vats. Less common artefacts of the cyanide process are the zinc precipitation boxes that survive in small numbers.

There are several ways of categorising the archaeological remains of cyanide vats; by the design of the vats; the material of construction; and size (Table 44). Vat design falls into three main classes: rectangular vats; round vats; and the tall thin B&M Agitators. The material of construction was timber, sheet iron, corrugated iron or concrete. Figures 279 to 284 illustrate these designs and materials. Size can relate to both the physical size of the vats, and the number of vats at a single site. Cyanide vats had a number of different purposes, such as solution vats, leaching vats and sumps, and sometimes it is possible to determine the purpose of an abandoned vat by its elevation relative to other vats and equipment; solution vats are likely to be at the top of the system, leaching vats in the middle and sumps at the lowest level.

**Table 44. Cyanide plants recorded during the archaeological survey.**
The number of tanks given is the number surviving on site (whole or in part).

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Vat type</th>
<th>Material</th>
<th>Dimensions</th>
<th>No.</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexander</td>
<td>L31/12</td>
<td>Circular</td>
<td>Corru. Iron</td>
<td>9ft 10in dia 13ft dia</td>
<td>9</td>
<td>1928</td>
</tr>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td>Circular</td>
<td>Corru. Iron</td>
<td>20ft dia 12 ft dia</td>
<td>7</td>
<td>1910</td>
</tr>
<tr>
<td>Big River</td>
<td>L31/4</td>
<td>Circular</td>
<td>Iron sheet</td>
<td>21ft dia, 18ft 6in dia 15ft dia</td>
<td>7</td>
<td>1908</td>
</tr>
<tr>
<td>Britannia</td>
<td>L29/15</td>
<td>Circular</td>
<td>Corru. Iron</td>
<td>14ft dia</td>
<td>3</td>
<td>1901?</td>
</tr>
<tr>
<td>Ferguson’s New Era</td>
<td>T13/104</td>
<td>Rectangular</td>
<td>Timber</td>
<td>10ft x 11ft</td>
<td>1</td>
<td>1889</td>
</tr>
<tr>
<td>Inglewood</td>
<td>L30/175</td>
<td>Circular</td>
<td></td>
<td>20ft dia</td>
<td></td>
<td>1903</td>
</tr>
<tr>
<td>Whangamata Gold Corporation (Luck at Last)</td>
<td>T12/601</td>
<td>Rectangular sumps</td>
<td>Concrete</td>
<td>11ft x 10ft 7 in</td>
<td>4</td>
<td>1899</td>
</tr>
<tr>
<td>Premier/Maryborough</td>
<td>F41/471</td>
<td>Circular</td>
<td>Timber</td>
<td>10ft 3in dia</td>
<td>3</td>
<td>Ca1898</td>
</tr>
<tr>
<td>Snowy River</td>
<td>L31/37</td>
<td>Circular, B&amp;M</td>
<td>Iron sheet</td>
<td>25ft dia 20ft dia</td>
<td>10 vats, 2 B&amp;M tanks</td>
<td>1908</td>
</tr>
<tr>
<td>Union (Waihi)</td>
<td>T13/303</td>
<td>B&amp;M</td>
<td>Concrete</td>
<td></td>
<td>6</td>
<td>1895</td>
</tr>
<tr>
<td>Victoria (fragments only)</td>
<td>T13/300</td>
<td>B&amp;M</td>
<td>Iron sheet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 279. In-ground circular timber cyanide sump at the Premier/Maryborough Battery (site F41/471).

Figure 280. Two 20 feet diameter circular corrugated iron cyanide vats at the Bendigo Battery (site T13/90).
Figure 281. Tarred sheet iron cyanide vats at the Big River Battery (site L31/4) in 2011.

Figure 282. The sheet iron cyanide vats at the Snowy River Battery (site L31/37). On the right are two B&M agitator vats (‘Pachucas’) for slimes treatment, and on the left a series of ordinary leaching vats for sand treatment.
Figure 283. Concrete B&M agitator vats erected in 1895 at the Union Battery, Waihi (site T13/303).

Figure 284. Rectangular concrete in-ground cyanide sumps at the Whangamata Gold Corporation (Luck at Last) Battery (site T12/601) in 2011.

There is now no known evidence of the very first generation of rectangular timber leaching vats built in 1889 at Karangahake, but some evidence of the contemporary cyanide plant built at Ferguson’s New Era Works in the Waiorongomai Valley possibly does survive. This plant included 12 rectangular wooden cyanide tanks (Figure 285) (Auckland Star, 11 February 1889: 3; Te Aroha News, 1 May 1889: 2), and on the cyanide house site there is a timber structure measuring approximately 11 feet by 10 feet, with vertical iron rods along two sides (Figure 286), that closely resembles the contemporary descriptions.
Figure 285. Isometric drawing of 1889 cyanide vat, extrapolated from 1889 AJHR partial drawing.

Figure 286. Cathleen Hauman (NZHPT) sitting on what are probably the remains of a rectangular timber cyanide vat at Ferguson’s New Era Reduction Works (site T13/104) in 2012.

Round timber vats survive at the Premier/Maryborough battery (site F41/471) (Figure 279 above) and the Snowy River Battery (site L31/37) (not visible in Figure 282 above). Only a few concrete cyanide tanks (as opposed to sumps, see below) survive, which given the durability of the material suggests that it was not much used for this purpose. The most notable survivor is the set of B&M agitator tanks at the Union Battery (site T13/303) in Waihi (Figure 283 above). A pair of concrete vats survived until the 1990s at the Deep Dell (Horse Flat) Battery (site I42/13) Hamel 1994b), but have since been destroyed by modern mining operations.

Concrete was more commonly used for sumps and foundations for cyanide tanks. A set of 4 concrete sumps is at the Whangamata Gold Corporation (Luck at Last) battery (site T12/601) (Figure 284 above), and concrete sumps are recorded amongst the Crown battery (site T13/284) foundations (Ritchie 1990: 185). The foundations for the B&M agitators at the Victoria Battery (site T13/300) are a notable feature of the historic reserve (Figure 287).
The most common material for cyanide tanks was iron; either sheet iron or corrugated iron (Figures 280, 281 and 282 above). The largest surviving intact cyanide plants are the Snowy River (site L31/37), Big River (site L31/4) and Bendigo (site T13/90) batteries, all of which have iron tanks. The Alexander Battery (site L31/12) includes a number of tanks but they have all been moved and damaged, and the site cannot be regarded as intact.

The other main artefact related to the cyanide process is the zinc precipitation box. Despite being made of timber, a number of these have survived, although all have some degree of decay, and all have been displaced from their original mountings. The largest single collection is at the Alexander battery (site L31/12), where 3 precipitation boxes have been placed on top of displaced cyanide tanks (Figure 288).
Other examples are at the Big River Battery (site L31/4) (2 intact and parts of a third, Figure 289), the Snowy River Battery (site L31/37), the Inglewood battery (site L30/175) and in the Hauraki Prospectors’ Association collection (ex Maratoto Battery, site T12/280). The examples from the Alexander Battery, Big River Battery and the Hauraki Prospectors’ Association collection (Maratoto) were measured in detail (Table 45), and match closely the contemporary drawings of long multi-chamber precipitation boxes (Figure 119 in Chapter 6). No examples of the earliest individual barrel-like boxes as used in 1889 at Karangahake were found.

![Image](image-url)

**Figure 289.** One of the two surviving precipitation boxes at Big River (site L31/4) in 2011.

**Table 45.** Zinc precipitation box measurements.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Chambers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexander</td>
<td>L31/12</td>
<td>13ft 2 ¼ in</td>
<td>20 ¼ in</td>
<td>25 in</td>
<td>8</td>
</tr>
<tr>
<td>Big River</td>
<td>L31/4</td>
<td>10 ft 6 ½ in</td>
<td>20 ¾ in</td>
<td>23 in</td>
<td>9</td>
</tr>
<tr>
<td>Maratoto</td>
<td>Ex T12/280</td>
<td>19 ft 1 in</td>
<td>27 ½ in</td>
<td>31 in</td>
<td>9</td>
</tr>
</tbody>
</table>

The archaeological evidence for the use of the cyanide process is therefore very good, partly due to the late nature of these sites (post-1889), but also due to the enthusiasm with which the process was adopted, especially after the Government purchased the patent rights in 1897. Of the sites described here, only the pioneering Ferguson’s New Era works pre-dates that year. The recorded cyanide plants match closely the contemporary accounts discussed in Chapter 6, and in particular the surviving B&M agitator tanks show a very close adherence to the formal design.
Smelting

The archaeological evidence of large-scale smelters (as opposed to small assay furnaces) in the gold mining industry is limited, with the Tarawera Smelter (site B45/29) in Preservation Inlet, Fiordland, being the main substantial remnant (Figure 290). The smelting of gold ores in New Zealand has often been unsuccessful, and the Tarawera Smelter only processed a single trial of 35 tons of ore in 1911 before being shut down (AJHR 1912 C2: 55). There are no known remains of the 1885 La Monte furnaces at Thames and Karangahake, nor of the 1888 Parkes furnace at the latter place. Several smelting complexes associated with copper mining survive, notably on Kawau Island and the Champion Smelter in the Dun Mountains, Nelson.

Figure 290. The inclined chimney at the Tarawera Smelter (site B45/29) in Fiordland.

Power Supply

Based on archaeological evidence, 60 of the surveyed sites have some evidence of their power source, of which 43 used water power, 9 used steam, 7 used internal combustion engines and 3 used electricity (2 mills used a combination of 2 sources).

Water Power

Many of New Zealand’s goldfields are in mountainous areas, where water was available at elevation, conditions suitable for the use of overshot or pitchback water wheels and various designs of water turbine. Contemporary photographs show that some very large water wheels were built to run stamp mills, but many of these were wooden and have left little evidence other than their cast iron hubs, a good example being the Invincible wheel (site E40/58) (Figure 291). Intact all-wood water wheels in original condition have now virtually disappeared from the goldfields, and the last surviving example was probably the small Canton water wheel (site H44/831) that has also now largely collapsed (Figure 292). However, a number of water wheels were built with cast iron rim structures, and a number of these have survived in various conditions, including the Victory (site H44/61) (Figure 294), the Young Australian (site F42/25) (Figure 293) and the Serpentine (site H42/2). Table 46 shows the water wheel remains that were recorded during the archaeological survey. The operational water wheels at the Mitchell’s Gully and Coromandel Government batteries are both modern.
Table 46. Water wheels (including fragmentary remains) recorded during the archaeological survey.
In each case the hub was iron, so the ‘Material’ column refers to the spoke and rim materials. O/shot = overshot, P/back = pitchback.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Type</th>
<th>Material</th>
<th>Dia</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Nations</td>
<td>F41/483</td>
<td>O/shot</td>
<td>Timber</td>
<td>19 ft</td>
<td>Battery</td>
</tr>
<tr>
<td>Alpine</td>
<td>F42/265</td>
<td>P/back</td>
<td>Iron</td>
<td></td>
<td>Battery</td>
</tr>
<tr>
<td>Canton</td>
<td>H44/831</td>
<td>O/shot</td>
<td>Timber</td>
<td>10ft 6in</td>
<td>Pumping/winding</td>
</tr>
<tr>
<td>Culliford</td>
<td>M28/4</td>
<td></td>
<td>Timber</td>
<td></td>
<td>Battery</td>
</tr>
<tr>
<td>Invincible</td>
<td>E40/58</td>
<td>O/shot</td>
<td>Timber</td>
<td>24 ft</td>
<td>Battery</td>
</tr>
<tr>
<td>Iris</td>
<td>Ex T11/625</td>
<td>O/shot</td>
<td>Timber</td>
<td></td>
<td>Battery</td>
</tr>
<tr>
<td>Moonlight</td>
<td>K31/10</td>
<td></td>
<td>Timber</td>
<td></td>
<td>Battery</td>
</tr>
<tr>
<td>Pleasant Ck.</td>
<td>E41/82</td>
<td>O/shot</td>
<td>Timber</td>
<td>7 ft 6in</td>
<td>Battery</td>
</tr>
<tr>
<td>Serpentine</td>
<td>H42/2</td>
<td>O/shot</td>
<td>Timber/iron</td>
<td>26 ft</td>
<td>Battery</td>
</tr>
<tr>
<td>Victory</td>
<td>H44/61</td>
<td>O/shot</td>
<td>Timber/iron</td>
<td>25 ft</td>
<td>Battery</td>
</tr>
<tr>
<td>Premier/Maryborough</td>
<td>F41/471</td>
<td>P/back</td>
<td>Timber/iron</td>
<td>30 ft</td>
<td>Battery</td>
</tr>
<tr>
<td>Young Australian</td>
<td>F42/28</td>
<td>O/shot</td>
<td>Timber/iron</td>
<td>26 ft</td>
<td>Battery</td>
</tr>
</tbody>
</table>

Figure 291. The Invincible water wheel (site E40/58) in 1995.
Figure 292. The small wooden Canton water wheel (site H44/831) in 1995.

Figure 293. The Young Australian water wheel (site F42/28) in 1993. This wheel has since been retimbered by the Department of Conservation.
Figure 294. The Victory water wheel (site H44/61) in 2010.

Of these wheels the Victory (Figure 294) is of particular note, as it was manufactured at A.K. Smith’s Carlton Foundry in Melbourne in 1863 (this is embossed on the castings), and is highly likely to have been part of the machinery at the Otago Mining Company’s battery at Waipori in 1863. It is almost certainly the oldest surviving water wheel, and probably the oldest surviving piece of machinery, in the New Zealand goldfields.

Water Turbines

Water wheels were large and cumbersome, and could only make limited use of high-head water supplies, and consequently compact water turbines that could utilise pressurised water supplies became popular in the goldfields. Several different forms are represented in the archaeological record, including various improvised flat-paddle designs, more formal designs such as the Whitelaw, and the most popular of all, the Pelton wheel.

Flat-paddle wheels, sometimes termed ‘hurdy-gurdy’ wheels, were inefficient, but several examples survive. The Fraser’s Gully Battery (site I44/517) had a small wheel made from two spoked dray wheels mounted on an axle, with a home made rim (Figure 295). Better engineered, but arguably little more efficient, is the flat-vane wheel at the No. 2 South Larry’s Battery (site L30/7) (Figure 296). This was a 1930s (Depression era) repair to a Pelton wheel that had been stripped of its cups (Letter from Inspector of Mines 29 May 1935; L. Wright pers. comm. 2013), and so is evidence of a retrograde step in technology for pragmatic reasons.
Figure 295. The improvised turbine wheel at the Fraser’s Gully Battery (site I44/517) in 1993.

Figure 296. The flat-vane wheel at the No. 2 South Larry’s Battery (site L30/7).

The Whitelaw turbine was used widely in the goldfields, and at least 5 survive (Table 47). The most complete example is at the Bella Reef Battery (site H44/556) (Figure 297), although nothing else remains on site, the battery itself having been moved to become the Crown (site B45/58) in Preservation Inlet in 1907. All other Whitelaw turbines on goldfields sites lack their supporting framework and housing, a good example being the Waimea battery parts (Figure 298).
Table 47. Whitelaw turbines identified in the New Zealand goldfields.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bella Reef</td>
<td>H44/556</td>
<td>1893</td>
<td>Complete</td>
</tr>
<tr>
<td>Croesus</td>
<td>L29/2</td>
<td>1883</td>
<td>Runner &amp; mount</td>
</tr>
<tr>
<td>Waimea</td>
<td>M28/5</td>
<td>1870 (second hand)</td>
<td>Runner &amp; mount</td>
</tr>
<tr>
<td>Southberg’s</td>
<td>E40/43</td>
<td>1866</td>
<td>2 runners in downstream debris</td>
</tr>
<tr>
<td>White’s Reef</td>
<td>G42/294</td>
<td></td>
<td>Runner &amp; mount</td>
</tr>
</tbody>
</table>

Figure 297. The Whitelaw turbine at the Bella Reef Battery site (site H44/556) in 2011.

Figure 298. The Whitelaw turbine runner (right) and mount (left) amongst the Waimea Battery parts (site M28/5).

Other turbine forms are also found in the goldfields, including a runner in the debris from the Phoenix/Achilles Battery (site E40/40) (Figure 299), and a complete Leffel turbine at an alluvial gold mining site at Tuapeka Mouth (site G45/23).
Figure 299. Turbine runner (right) and compressed air receiver (left) in the streambed immediately downstream of the Phoenix/Achilles Battery (site E40/40) in 2011.

The most popular turbine in the goldfields (as well as in other industries) was the Pelton wheel (Figure 300) that was first introduced to New Zealand in 1884. Twenty-three Pelton wheels were recorded during the archaeological survey (Table 48), not counting many unprovenanced examples in various museum collections. They range from 4 feet 1 ½ inches to 9 feet 3 inches in diameter, but most are nominally 6 feet diameter.

Figure 300. Pelton wheel at the Whangamata Gold Corporation Battery (site T12/601).
Table 48. Pelton wheels in the New Zealand goldfields.
The diameter is measured across the tips of the cups, unless stated otherwise (when the cups are missing).

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Diameter</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>B46/42</td>
<td>5 ft 10 in</td>
<td>2 wheels, 1 for battery 1 for winding</td>
</tr>
<tr>
<td>Alpine</td>
<td>L29/3</td>
<td>6 ft</td>
<td>1st on West Coast</td>
</tr>
<tr>
<td>Anderson’s</td>
<td>F41/473</td>
<td></td>
<td>Pelton missing, housing present. A&amp;G Price</td>
</tr>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td></td>
<td>Buried in debris</td>
</tr>
<tr>
<td>Big River</td>
<td>L31/4</td>
<td>6 ft 4 in</td>
<td></td>
</tr>
<tr>
<td>Bolitho’s/Watt’s</td>
<td>L30/174</td>
<td></td>
<td>Pelton missing, mounting &amp; nozzle present</td>
</tr>
<tr>
<td>Britannia</td>
<td>L29/15</td>
<td>6 ft</td>
<td></td>
</tr>
<tr>
<td>Bullendale powerhouse</td>
<td>E48/20</td>
<td>6 ft</td>
<td>2 wheels running dynamos</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>H44/745</td>
<td>4 ft 6 in</td>
<td></td>
</tr>
<tr>
<td>Crystal</td>
<td>E41/91</td>
<td>4 ft 1 ½ in</td>
<td></td>
</tr>
<tr>
<td>Garden Gully</td>
<td>K31/51</td>
<td>6 ft</td>
<td></td>
</tr>
<tr>
<td>Golden Lead</td>
<td>L31/29</td>
<td>6 ft 2 in</td>
<td></td>
</tr>
<tr>
<td>Golden Site (Battery)</td>
<td>B46/41</td>
<td>6 ft 2 in</td>
<td>‘A&amp;G Price, Thames, No. 149 Pelton’s Patent.’</td>
</tr>
<tr>
<td>Golden Site (Winding)</td>
<td>B46/41</td>
<td>5 ft</td>
<td>‘A&amp;G Price, Thames, No. 150, 1894…’</td>
</tr>
<tr>
<td>Kirwan’s Reward</td>
<td>L30/62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whangamata Gold</td>
<td>T12/601</td>
<td>6 ft</td>
<td>Pelton Water Wheel Co., S.F.</td>
</tr>
<tr>
<td>McNichol’s</td>
<td>E40/34</td>
<td></td>
<td>Buried in slip</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>5 ft 2 in (rim)</td>
<td>Cups missing.</td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>5 ft 10 ½ in</td>
<td></td>
</tr>
<tr>
<td>Taitapu</td>
<td>M25/86</td>
<td>6 ft 1 in (rim)</td>
<td>Cups missing.</td>
</tr>
<tr>
<td>Woodstock</td>
<td>T13/289</td>
<td>9 ft 3 in (rim)</td>
<td>All exposed cups smashed.</td>
</tr>
</tbody>
</table>

The New Zealand rights to manufacture the Pelton wheel were held by A.&G. Price of Thames, and most wheels with an identifiable maker came from this company. One imported American Pelton wheel, manufactured by the Pelton Water Wheel Company of San Francisco, was recorded at the Whangamata Gold Corporation (Luck at Last) Battery (site T12/601) (Figure 300). The maker’s name is embossed on the spokes, and the cups carry the patent date of October 26th 1880. The oldest surviving Pelton wheel in New Zealand is probably the example at the Alpine Battery (Figure 301) (site L29/3) that was installed in 1884, and was (according to the goldfields warden) the first on the West Coast (AJHR 1885 C2: 38). Another two early Pelton wheels, manufactured by A.&G. Price, are located at the Phoenix power house (site E48/20) where they were installed in 1885 (AJHR 1887 C5: 46) (see Figure 329 in Chapter 10).
Most Pelton wheels are of a similar construction, consisting of a one-piece cast iron 6-spoke wheel, with the cups bolted to the rim (Figures 300 and 301). A notable exception is the largest surviving known wheel, at the Woodstock Battery (site T13/289), which was fabricated from separate hub, rim and wrought iron spokes (Figure 302).

The efficiency and simplicity of the Pelton wheel meant that it was widely adopted after its 1884 introduction, and the design is still used today. The archaeological record reflects this popularity, as despite the obvious attractions of removing Pelton wheels from battery sites for reuse or scrap, large numbers have survived in place.
Steam Engines

Steam engines were commonly used in the goldfields, despite their expense of operation, and many were removed for re-use elsewhere even if the rest of the battery equipment was abandoned on site. This happened at Johnston’s United battery (site M25/73), where the stamp mill was left intact but the steam engine and boiler were taken away. At Printz’s Battery (site D46/150) this process was started but never completed, as both the engine and boiler have been dismounted and moved a short distance, but were then abandoned (Figure 303). Boilers were often abandoned when they wore out, and a number of steam-powered sites retain the boiler without the associated engine. However caution must be exercised in interpreting such sites, as boilers were sometimes used to provide steam to heat the gold recovery process, not for power, such as at the Maratoto Gold-Mining Company’s pan amalgamation plant (site T13/276) and the Premier/Maryborough Battery (site F41/471).

Substantial remains of 6 steam engines were recorded, together with 3 additional sites with boilers or boiler settings (Table 49). Many more abandoned boilers are known to exist, but these were not specifically sought out.

Table 49. Battery sites with substantial evidence of steam power plant.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No</th>
<th>Engine</th>
<th>Boiler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajax</td>
<td>L30/31</td>
<td>Single cyl.</td>
<td>Cornish</td>
</tr>
<tr>
<td>Albion</td>
<td>Q27/112</td>
<td>Single cyl.</td>
<td>Multi-tube</td>
</tr>
<tr>
<td>Inglewood</td>
<td>L30/175</td>
<td>Single cyl.</td>
<td>Brick boiler house remains</td>
</tr>
<tr>
<td>Johnston’s United</td>
<td>M25/73</td>
<td></td>
<td>Brick boiler setting remains</td>
</tr>
<tr>
<td>Morning Star</td>
<td>B46/49</td>
<td></td>
<td>Portable</td>
</tr>
<tr>
<td>Printz</td>
<td>D46/150</td>
<td>Single cyl.</td>
<td>Lancashire</td>
</tr>
<tr>
<td>Welcome jack</td>
<td>T11/693</td>
<td>‘Tangye Colonial’</td>
<td>Multi-tube</td>
</tr>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Single cyl.</td>
<td>Multi-tube</td>
</tr>
<tr>
<td>Talisman</td>
<td>T13/286</td>
<td>Large crankshaft</td>
<td></td>
</tr>
</tbody>
</table>

Figure 303. The Lancashire boiler and dismounted engine flywheels at Printz’s Battery (site D46/150).
Internal Combustion Engines

The internal combustion engine is more efficient and compact than the steam engine, and there is good evidence that it was commonly used during the twentieth century. In common with many other items of machinery, internal combustion engines had value and were rarely abandoned on site, and so are not common in the archaeological record, but evidence of the use of both gas and oil engines does exist. Callery’s Battery (site I42/161), is powered by a Tangye oil engine that is still operational (Figure 305), and a vertical Ruston diesel is still in place at the Lillis Battery (T10/773) (Figure 306).

Figure 305. The Tangye single-cylinder horizontal engine at Callery’s Battery (site I42/161).
Other engines in the goldfields are more fragmentary. There are some parts of an engine at the Eureka battery (site E41/51), and the 1930s Crystal Battery (E41/91) once had several automotive engine blocks beside it (now washed away by floods), as well as the Pelton wheel that still survives. Evidence of the use of gas engines was recorded at two mills, the Golden Bar (site I43/88) and Buckland’s (I43/99). At the former the concrete engine bed indicated that an engine with flywheels was used, and a nearby concrete pad had the circular impression of the gas producer, and was surrounded by clinker and segmental fire bricks. At Buckland’s Battery the crankshaft from the engine and the gas producer survive (Figure 307), together with a pile of coal dross and lots of clinker.

Figure 306. The twin cylinder Ruston engine at the Lillis Battery (site T10/773).

Figure 307. The gas producer at Buckland’s Battery (site I43/99), Barewood
The maker’s name, ‘Tangye, Birmingham,’ is cast on one hatch cover.
Electric Power

The mining industry pioneered the use of industrial-scale electrical generation in New Zealand at Bullendale in 1885-86, and the history and archaeology of this site are well documented (AJHR 1886 C4: 19; 1887 C5: 46; Chandler & Hall 1986; Petchey 2006a, 2013; Ritchie 1985). The surviving evidence consists of the substantial remains of the dynamos and their drive system, the bases of the power poles to the battery site, and the electric motor that drove the stamps (Figure 308 and see Figure 328 in Chapter 10).

Figure 308. The disassembled Brush Corporation ‘Victoria’ electric motor at Bullendale (site E40/47).

At the Premier/Maryborough Mine (site F41/480) near Macetown a generator was installed at the battery in 1895 to provide power for an electric winch in the mine (AJHR 1897 C3: 120), and a control unit survives in the valley a short distance above the battery site (Figure 309), together with insulator fragments scattered about the battery site.

Figure 309. The electrical control unit at the Premier/Maryborough Mine (site F41/480).

The most intact archaeological evidence of a goldfields electrical power house is the Waihi Mining Company’s 1910-1913 Horahora Power Station (site T15/195) that was inundated by lake Karapiro in 1947. The power house still stands largely intact beneath the waters (Figure 310), and parts of two generators have been placed on the nearby riverbank (Figure 311) after a 1970s salvage project removed much of the generating equipment for scrap.
Figure 310. Sonar image of the Horahora Power Station (site T15/195) in Lake Karapiro, taken in 2011 (Tech Dive NZ).

Figure 311. David Petchey standing beside the most intact of the two surviving Siemens Brothers rotors from the Horahora Power Station in 2011. It is standing on end, but its working position was with the shaft horizontal.
Chapter 10

The International Context of New Zealand Stamp Mill Technology

As the previous two chapters show, New Zealand has a good archaeological record of stamp mills and associated plant, albeit with the various biases identified in Chapter 7, and that in most ways the surviving mills fit well within the technological parameters described in the contemporary literature (Chapters 5 and 6). At a general scale the international origin of this technology comes as no surprise: Burt (2000: 321) commented that the nonferrous mining industry is and always has been one of the most international of industries in terms of its organisation, finance and diffusion of technical knowledge, and other authors have made similar comments (eg Menghetti 2005: 204). The concepts of World-Systems Theory and Technological Dependence (or Dependency Theory) were introduced in Chapter 2, and Burt’s (2000) central thesis was that the American nonferrous mining industry was technologically dependent on Europe until the end of the nineteenth century. Making an important link between economic theory and archaeological evidence he summed up his paper thus:

“Perhaps the best evidence of the general thesis offered here, however, is to be found not in the written but the archaeological record. The technological detritus of the smaller abandoned mining camps of the West- the washing facilities, the head gears, the cyanide drums, the dynamite boxes, and so on- clearly betray their European origins and in no significant way distinguish American sites from others of the same period found in mining districts across the world” (Burt 2000:347).

Although using this definitive statement out of full context is slightly unfair on Burt as he presented it as an admitted controversial position, and did state that although nowhere did Americans take the lead in major innovative developments, they did dominate in the evolution of milling and concentration processes such as the stamp mill (Burt 2000: 326), it does provide a very good starting point for the discussion of New Zealand’s position in the global context. At a general level the New Zealand archaeological evidence appears to support a Dependency Theory model (with the concepts of a technological ‘core’ supplying a global ‘periphery’), as although there are departures from ‘ideal’ international practice, most evidence fits within the international parameters described in Chapters 5 and 6. Even the differences, such as the extensive use of the lightweight ‘A’ frame and heavier trestle frame, can be explained by the bias in the contemporary literature towards larger mills (as discussed in Chapters 2 and 7). Burt’s statement above suggests that the archaeological evidence found worldwide should indicate European origins, but the New Zealand evidence is for distinctive American and Australian influence as well as European (predominantly British) influence. There are multiple ‘cores’ of influence, with a hierarchy amongst those cores: the situation is clearly far more complex than Burt’s statement would indicate.

In addition, the overwhelming presence of overseas technology does not necessarily prove dependence. As also outlined in Chapter 2, Todd (2009: 247) and Menghetti (2005: 218) raised the concept of ‘Technological Sovereignty’ rather than technological dependency, whereby informed decisions were made to seek out international technology, after which it was adapted to suit local requirements. In terms of World-Systems Theory, this suggests that the periphery is not entirely dependent on the core, but is exercising agency in the selection and use of technology. They key to interpreting and understanding the archaeological evidence is therefore not to simply identify international design features, but also to consider
how they were selected, used and adapted in New Zealand, and how various agents and influences affected those choices.

The answer therefore lies not only in the individual assessment of design feature by design feature, but also by the way that these various design features evolved and were combined and used together in complete stamp mills in New Zealand, and how these complete mills illustrate change and development over time and in response to various international, national and local influences. The concepts of macro- and micro-innovation that were introduced in Chapter 2 provide a useful framework for this examination.

**Macro- and Micro-Innovation**

The evolutionary concepts of macro- and micro-innovations have been applied to mining technology by Burt (2000), and other economic historians have used similar concepts by looking at innovation and adaptation in the goldfields (e.g., Limbaugh 1998; Newell 1985; Menghetti 2005). It has been generally agreed that with the exception of a few major innovations (such as the cyanide process and the Blake rock crusher), most goldfields technology was evolutionary in nature, and the radical inventions that did occur were in turn subject to evolutionary change (see Mokyr 1990: 13-14). In particular, the stamp mill itself was a micro-innovation from 1850s California, and its subsequent development was an ongoing series of further micro-innovations. In general, any successful macro-innovation should be followed by a process of micro-innovation as the new invention was developed and adjusted to suit different locations. Writing with regard to the Australian goldfields, Menghetti (2005: 207) has observed that evolutionary technologies were often more easily adopted in the goldfields than radical new innovations, and that the importation of new machines did not necessarily lead to the transfer of technology, as the machine might fail to perform in the new environment and be abandoned (see also Todd 2009: 210).

If all these points are valid, the archaeological record should provide evidence of on-going evolutionary change (micro-innovation) with occasional large innovative jumps (macro-innovation), some of which are dead ends and some of which themselves are followed by gradual change (further micro-innovation). Critical issues are to determine the nature and origins of the various changes, and to identify the influences of overseas control, local agency and other local factors (such as environment and geology), thereby identifying Technological Dependency or Technological Sovereignty, or (as is discussed further below) any alternatives.

**Case Studies**

In order to study how these processes were played out in the real world, and how the various component parts described in Chapters 8 and 9 were married together in practice, eight cases studies are discussed below (see Figure 312). These examples are chosen to illustrate a number of aspects of mill technology, including change over time, ‘typical’ small mills, the adoption of new technology, and the influences of international finance and equipment. Wherever possible the ‘early’ and late’ biases identified in Chapter 7 are addressed by determining when a mill was manufactured, and when it was moved to its present site.
The studies are:

1. The Nugget (Shotover) Battery as an example of change through time at one site from the 1860s to the 1900s.
2. The Young Australian Battery, as an example of a typical early mill that has been used, moved, repaired and worn out.
3. The Albion Battery, as an example of a typical iron-framed ‘Australasian’ mill.
4. Bullendale (Phoenix Battery), where electric power was first introduced to stamp milling, as an example of cutting-edge international technology being adopted.
5. The Eureka, as an example of a small American-manufactured stamp mill.
6. The Homeward Bound, as an example one of the largest surviving mills, and an international design placed directly in the New Zealand Goldfields, paid for by international finance.
7. The Snowy River Battery, as an example of the uptake of the cyanide process and the adoption of New Zealand modifications, also paid for by international finance.
8. The Bendigo Battery, as an example of the ‘normalisation’ of international technology in a locally manufactured mill.

Figure 312. The locations of the 8 case study sites.
Case Study 1: The Nugget Battery, Shotover River

The Nugget Battery (site F41/23) is a large timber-framed 10 stamp mill beside the Shotover River in Otago. The battery site began life in the early 1870s using second-hand 1860s machinery, and was subsequently completely rebuilt several times. The present stamp mill dates to 1903, but evidence of earlier incarnations survives on site.

The Nugget claim was established in the late 1860s, and in 1870 the Nugget Quartz Mining Company purchased the second-hand Perry, Watt & Company Battery from nearby Skippers Creek, which in turn had been had been purchased from Melbourne in 1865. At the time of its construction it was described as being on the “latest and most improved principles,” and consisted of 24 head of stamps, 4 to a box (Otago Witness, 5 May 1866: 8). The Nugget Company only erected 12 stamps at their new battery site beside the Shotover River. These were about 6cwt. each, working in three mortar boxes, using amalgamating plates and a revolving barrel to save gold, with power supplied by a ‘turbine wheel’ (Ulrich 1875: 86).

In 1883 the Gallant Tipperary Company purchased the operation, by which time the battery was very out of date, and the Mines Inspector commented in 1889 that “there is not at present a mining company in the colony who is using a more defective crushing-plant” (AJHR 1889 C2: 58). The historical records then contain numerous stated intentions to rebuild the machinery, but it is not clear how much action was taken. In 1897 the Gallant Tipperary company went into liquidation and the mine was purchased by the Shotover Quartz-mining Company, who did undertake a complete rebuild. A new Cossens & Black ten stamp mill and a cyanide plant were installed in 1903, replacing all the earlier machinery. However, by 1906 the company had exhausted its funds, and the mine was let on tribute until about 1909 and subsequently the battery was abandoned on site. The ‘Nugget’ name has stuck up to the present day, despite the several changes in ownership, although the correct name should actually be the ‘Shotover’ battery.

The site of the Nugget (Shotover) Battery is on the true right bank of the Shotover River (Figure 313). The stamp mill stands at the foot of the hillside at the back of the site. At the front and upstream side are the remains of the stone wall that supported the battery terrace, which was where the cyanide plant stood. Built into the surviving section of the retaining wall are two old mortar boxes, three iron gear wheels and an amalgamating barrel (Figure 314). Sections of two more discarded mortar boxes are lying loose on the site (Figure 315).

Figure 313. The Nugget Battery (site F41/23) in 2011

The timber stamper frame is a conventional front-braced vertical post structure on timber foundations, with timber mortar blocks. This form of framing is typical for the size and date
of the battery, although by 1903 concrete was a viable alternative for the foundation work. The machinery itself exhibits a mixture of contemporary and conservative practice for 1903. The stamps are approximately 720 lb each (calculated from on-site measurements), placing the mill in the mid-weight range. Gib tappets are used, appropriate for the age and stamp weight. A single camshaft carries all ten cams, with thecams mounted using conventional keys in keyways. Only right-handed cams were used, with the lateral thrust being resisted by the mounting of the main drive pulley against one outside cam bearing. The mortar boxes are sectional, with cast iron lower halves and sheet iron upper sections, suitable for the mountainous setting. The screen mounts are inclined slots, which was appropriate for the time. Wear on the stamp heads and worn shoes and dies indicate that the battery had done a reasonable amount of work, but it is by no means worn out, with the cams, tappets and mortar boxes in good condition. Power was supplied by a Pelton wheel, which is still present although incomplete.

The four discarded mortar boxes are of two types. The two that have been incorporated in the retaining wall (Figure 314) are sectional boxes, with cast iron lower halves and sheet iron upper sections. They are both 4-discharge boxes, with outlets at the front, back and sides. The side outlets have been plated over and the side pulp channels cut away, indicating that they were converted to conventional front-discharge during their working life. The two loose mortar boxes (Figure 315) are also sectional, although the sheet iron upper sections are missing. These boxes are more conventional, with ordinary front outlets only. They are almost identical to the two remaining boxes at Southberg’s Battery (site E40/43), suggesting that they were possibly brought from that site. All 4 discarded boxes have vertical bolt-on screen mounts.

**Figure 314. Mortar boxes, gears wheels and an amalgamating barrel built into the retaining wall at the Nugget Battery.**

**Figure 315. Two loose mortar box bottom sections in front of the Nugget Battery.**

The archaeological evidence at the Nugget Battery is therefore that there were three main phases of battery construction. The first phase in 1870 probably used mid-1860s multiple-discharge mortar boxes (ex-Perry Watt & Co), which were not uncommon in that period. However, it is clear that they were not effective, as the extra outlets were blanked off during their working life. These mortar boxes were then replaced with boxes of a more conventional single-discharge design (possibly taken from Southberg’s Battery), but still with vertical bolt-on screen mounts, that were themselves finally replaced in 1903 by the in-situ boxes with inclined slot mounts. This progression in box design and screen mount is in
keeping with the discussion in Chapters 5 and 8. It is of note that all of the boxes at the site are ‘sectional,’ designed to be broken down for transport in difficult terrain. This evidence of environmental influence, also seen at the nearby Phoenix/Achilles (site E40/40) and Southberg’s (site E40/43) batteries, is readily appreciated in the steep and mountainous location of all three sites.

The Nugget Battery therefore provides good evidence of change over time, with the evolution of ideas regarding mortar box design clearly illustrated. The earliest machinery was manufactured in Australia, and reflects current thinking at that time. The final form was manufactured in New Zealand, and shows a mixture of conventional (key mounted cams, no provision for lateral thrust, timber mortar blocks) and up-to-date practice (slotted inclined screens, gib tappets) for 1903. As the Shotover Quartz Mining Company was a New Zealand (Dunedin) company, it illustrates how local finance purchased well-proven but conventional locally-made machinery.

Case Study 2: The Young Australian Battery, Carrick Range

The Young Australian (site F42/25) in Adams Gully in the Carrick Range in Otago is a small New Zealand made stamp mill. What sets this battery aside from many others is the degree of wear; while some stamp mills were abandoned with little or moderate visible wear, the Young Australian appears to have been operated until it was completely worn out. It has had a number of repairs, and even the repaired items are visibly at the end of their useful lives.

The machinery now at the Young Australian Battery was manufactured in 1871 by Kincaid McQueen & Co. of Dunedin for Andreas Iverson’s Conroy’s Reef near Alexandra, and in 1874 it was sold to Williams & Edwards at the Young Australian claim in the Carrick Range. At that date it was described as a 10 stamp mill with both amalgamating tables and blanket strakes (Ulrich 1875: 83). The date the mine closed is not known, but it had been abandoned for many years when McCabe & Sons of Bannockburn reopened it in 1896. It was possibly at this time that half of the mill was transported across to Adams Gully, but the water wheel was abandoned in place, where it remains today. Water power was used in the new location to power the (reduced) 5 stamp mill, and although the type was not specified it was almost certainly a Pelton wheel. This venture lasted for only a few years, and work ceased in 1898. The battery was abandoned on site, where it still stands today (Figures 316 & 318).

Figure 316. The abandoned Young Australian Battery and water wheel in 1939. (Auckland Weekly News, Sir George Grey Special Collections, Auckland Libraries, AWNS-19391025-45-4).
The site of the Young Australian Battery is on a terrace cut into the east side of Adams Gully, with the battery and Berdan at the southern end of the terrace, and a building site and stone hearth at the other end (Figure 319). Figures 316 and 318 show the site from the same viewpoint in 1936 and 2011. The water wheel still stands on the hillside opposite, where it was erected in 1874 (Figure 317).

Figure 317. The Young Australian Water Wheel in 1993.

Figure 318. The Young Australian battery in 2011, from the same viewpoint as the 1936 image above.
Figure 319. Plan of the archaeological features at the Young Australian Battery in 2011.

The battery structure is a basic timber A-frame, on conventional timber foundations. A sub-frame at one end supports the drive gears for the camshaft, and a frame at the other end supports the end of the long (10 stamp) camshaft. The mortar blocks are timber, although investigation for a condition report in 2001 found that a concrete collar had been cast around the blocks (Mason 2001). The mortar box is a conventional one-piece cast iron item, with vertical bolt-on screen mounts and front outlet.

Figure 320. A rear view of the Young Australian Battery in 2011, showing the A-frame, geared camshaft drive and the Berdan.

The stamps are light, with a calculated weight of 566lb, and have simple collar tappets that all show evidence of extreme wear, with iron bands shrunk on to hold them together (Figure 321). The shoes are all relatively unworn, and had been replaced not long before the battery was abandoned. Although set up as a 5 stamp mill, the 10 stamp camshaft from the earlier (1871) configuration has been retained, with the ‘unused’ end supported by a trestle frame. The cams are secured by keys, and are all badly worn with repair sections riveted on their lifting faces (Figure 321). Number 5 cam is of a different hand and profile, and is almost certainly a replacement due to the failure of the original cam. The remains of wooden tables and mercury traps indicate that amalgamation tables were used, and the Berdan
for grinding concentrates is still in place. An amalgamating drum has been rolled into the gully below the battery.

Figure 321. The camshaft and stamp stems in the Young Australian Battery in 2011.

The choice of power source is notable. The original water wheel was manufactured in Dunedin in 1871, and is a well-engineered overshot wheel (Petchey 1996). And yet, while considered worth moving in 1874, it was abandoned on site when the battery was later relocated. Its replacement is now missing, but the surviving reduction gears on the camshaft indicate that a high-speed power source was used, which was most probably a Pelton wheel.

The Young Australian Battery illustrates typical locally-manufactured technology of the early 1870s, with timber A-frame, lightweight stamps, key mounted cams and tappets, simple mortar box form and basic gold saving by amalgamation. When initially manufactured for use at Conroy’s in 1871 it would have been a typical battery of its size, and when moved to the Carrick Range in 1874 it would still have been an example of acceptable practice. But by 1896-1898, when it was last operated, it was very out of date. The only obvious concession to updating the machinery during its life was the change from the old water wheel to water turbine power. However, despite being light and out-dated, it is clear that it did a lot of work, and the cams and tappets in particular show extreme wear. The extensive repairs to these must have been a pragmatic and cost-saving exercise, as they were service parts that could be changed, and this aspect of the battery’s history is explored below in Chapter 11.

Case Study 3: The Albion Battery, Terawhiti.

The Albion Battery (site Q27/112) represents the smaller iron-framed ‘Australasian’ battery. It was erected in 1882 by the Albion Gold Mining Company (Wellington based), using second-hand Langlands (Melbourne) machinery purchased from Nelson, powered by a new steam engine and boiler manufactured in Wellington by Luke, Sons & Williams. The identity of the Nelson battery has not been determined, but it is most likely that the machinery was
manufactured in the 1870s. Two Berdans (from Melbourne) were installed in 1885, and the battery was last used in 1886. It was dismantled to be moved in 1912, but most of the machinery was left on site. The Albion site today consists of the dismantled parts of the iron-framed ten stamp mill, two Berdans, boiler and steam engine (Figure 322). Although they are disassembled, the main parts appear to still be correct position in relation to each other.

**Figure 322. The Albion Battery site in 2011.**

The battery frame is cast iron, of the Type 1A design discussed in Chapter 8; that is, it has a square/octagonal/round section battery post, with bearing mounts for both the camshaft and lineshaft. The camshaft is a one-piece item for all ten stamps, and the cams are mounted using conventional keys in keyways. The stamps weigh 480 lb (calculated weight) and have screw-mounted tappets (Figure 323). The mortar boxes are conventional one-piece cast iron items, with vertical bolt-on screen mounts and bolt holes for internal wear plates. The steam engine is a single cylinder horizontal unit, with an underfired multi-tube boiler. The battery does have some evidence of wear, with several of the cams showing damage at the point where they struck the tappets. This is indicative of the battery having done a reasonable amount of work, and although it was only used intermittently for 4 years in its present location, it did an unknown amount of work in Nelson.

**Figure 323. Some of the dismantled battery posts and stamps from the Albion Battery.**
Despite the large steam engine and ornate cast iron parts giving the Albion Battery the superficial appearance of being large and well-engineered, it actually displays resolutely conventional technology. The stamp weight of 480lb places it in the upper end of the lightweight range, and the screw-mount tappets were out of date by the 1880s. This is typical of the Type 1 and Type 1A batteries, which all display conventional engineering, although several operated well into the twentieth century. With some variation, these characteristics are commonly found in batteries manufactured both in New Zealand (R. Sparrow & Co., A.&G. Price, J. Moutray) and Australia (Langlands). The use of conventional technology and second hand equipment supports the model that New Zealand based mining companies often invested in cheaper, more conventional plant, in contrast to the large expensive plant imported by the London based companies.

Case Study 4: Bullendale & the Adoption of Electric Power

Bullendale is situated in the Right Hand Branch of Skippers Creek, a tributary of the Shotover River, in Otago. The name “Bullendale” is more correctly applied to the settlement that grew up around the Phoenix (after 1893 the Achilles) gold mine, but is now used commonly for the whole mine complex. The Phoenix Battery (site E40/40) and power house (site E40/28) are on either side of Southberg’s Spur.

The Scandinavian Company (which later became the Phoenix Company) erected a 4 stamp mill in 1864, which they replaced in 1866 with a 30 stamp battery from A.K. Smith’s Carlton Foundry and a turbine wheel from Langlands & Co., both of Melbourne. The battery was equipped with 6 cwt stamps, mercury troughs, blanket tables and an amalgamation barrel, and a roasting furnace was used for a short time (Ulrich 1875: 87). Numerous alterations were made over the years, but the basic 30 stamp configuration remained for the rest of the life of the mill. In the 1880s problems with the water supply for the water turbine encouraged the owner, George Bullen, and his manager, Fred Evans, to investigate the use of hydro electricity. With the advice of Walter Prince and Robert Fletcher of R.E. Fletcher & Co. they decided to install a hydro-electric plant in the other branch of Skipper’s Creek. The powerhouse contained two A.&G. Price Pelton wheels driving a pair of Anglo-American Brush Corporation dynamos (Figure 324).

Figure 324. The two Brush Corporation dynamos in the powerhouse in 1886 (Lakes District Museum, EL0967).

A transmission line carried the power over Southberg’s Spur to the battery house, where a Brush Corporation "Victoria" electric motor was installed to drive the stamps. The dynamos were first trialled in
February 1886, and after some teething trouble and subsequent modifications they were run until about 1901 when the mine closed. When it reopened between 1903 and 1907 the electrical system was not repaired, and a Pelton wheel at the battery house was used instead.

The archaeological evidence of the Phoenix/Achilles battery and associated electrical system are scattered over a wide area. The battery house site (site E40/40) is at the junction of the Right Hand Branch of Skippers Creek and Murdoch’s Creek, the electric motor has been moved to the nearby New Main Shaft site (site E40/47), and the power house site (site E40/28) is beside the Left Hand Branch of Skippers Creek. The remains of the power line can still be traced across the intervening Southberg’s Spur.

The battery has been badly damaged by fire, scavenging and flood, but some equipment survives on site. The Kincaid & McQueen rock breaker is still in situ (Figure 325) at the top of the ore hopper (which is cut into the bedrock), and below it the timber mortar blocks for the 30 stamps show how the battery was arranged. Three mortar boxes remain on site, one of which is still on its mortar block (Figure 326). Another partial box is lying in the bed of Murdoch’s Creek. They are sectional boxes with sheet iron upper sections and cast iron bases, and have vertical bolt-on screen mounts.

**Figure 325. The Kincaid & McQueen rock breaker on a spur above the Phoenix/Achilles Battery site.**

A number of stamps, one camshaft and several discarded cams are also present. There is a variation in sizes and patterns of most parts, with several different tappet designs and cam sizes. The cams are mounted with a conventional key and keyway, and some show damage and severe wear. Some of the stamp stems also show wear where they have been sliding in the iron guides, one of which also survives. The debris field around the battery and in the downstream streambed contain numerous items of machinery, including a Berdan, a compressed air reservoir and a water turbine runner.
The New Main Shaft winding house (site E40/47) is located north of battery site, on a terrace cut into the steep valley side of Murdoch’s Creek. The site has extensive evidence of the winding and pumping equipment, including the Brush Corporation electric motor that was originally installed in the battery house. The motor has been dismantled to remove the copper windings, but the main castings survive (Figure 327).

Figure 327. The dismantled Brush Corporation Victoria electric motor at the New Main Shaft site.

The powerhouse site (site E40/28) on the south side of Southberg’s Spur was partially restored in 1986 to mark its centenary, when the Brush Corporation dynamo beds, intermediate shafts and Pelton wheels were mounted on replica timber framework (Figures 328 and 329).

Figure 328. The two Brush Corporation dynamos at the Phoenix power house site in 2011.
Figure 329. The two 1885 A.&G. Price Pelton wheels at the Phoenix power house site.

The Phoenix/Achilles battery and associated powerhouse site are significant in a number of ways. The battery was one of the earliest large mills to be erected in the New Zealand goldfields in 1866. It is not clear how much of this early equipment survives, but the existing mortar boxes are of an early design, with vertical bolt-on screen mounts, and the surviving stamps and cams also show conventional design technology. The battery therefore shows evidence of its long life, beginning in the 1860s and continuing in service until the early twentieth century, using conventional processing technology.

This somewhat dated battery design stands in stark contrast to the evidence of the electrical system. The dynamos were the largest and most advanced electrical plant in New Zealand when they were installed, and the Pelton wheel was the latest, and as time would show most successful, form of water turbine in the goldfields. All of the main elements of the electrical system were therefore state-of-the-art for the period.

Case Study 5: The Eureka Battery, Skippers

The Eureka Battery (site E41/51) is a small two stamp mill situated beside Jennings Creek at Skippers, in Otago. It is an example of the distinctive imported American triple-discharge 4 post machines described in Chapter 8.

The Eureka Gold Mining Company was formed in Reefton in about 1902 to work a reef in Jennings Creek. In 1905 the company erected a ‘patent two-head’ stamp mill powered by an oil engine, and began crushing in early 1906. However, the throughput of the machine was too low to be economical, and the claim was abandoned. In 1907 a prospecting party received a government grant to reopen the mine, but this appears to have come to little.

Figure 330. The Eureka Battery (site E41/51) in 2011.

The Eureka Battery is located on the true right of Jennings Creek, on the floor of the very steep valley. The stamp mill machinery is all present (Figure 330), but the timber frame has largely rotted away, and only a few parts of the oil engine remain.

The mill was fitted with a four-post timber frame, each post being bolted to one corner of the mortar box. This box (Figure 331) is a triple-discharge design, with front and side outlets,
each outlet being fitted with an incline slot screen mount. The box is embossed with the maker’s name; “Joshua Hendy Machine Works, S.F. Cal.” The stamps are heavy for a 2 stamp machine, with a calculated weight of 780 lb each, and they are fitted with gib tappets. The camshaft is correspondingly heavy, 4 7/16 inches in diameter, and Blanton type cams are fitted.

Figure 331. The triple-discharge mortar box at the Eureka Battery.

The Eureka Battery is an example of an imported American machine, and shows some very different approaches to design to the other seven mills discussed here. The basic elements of the stamp mill are present, and show many advanced features, including the heavy stamp, gib tappet, Blanton cam and slotted inclined screens. However, the use of multiple discharge was not generally favoured after the 1870s, and the use of the 4 post frame (in timber or iron) was generally limited to other similar American machines. It therefore displays technological features (micro-innovations) in keeping with other mills for its period, but its configuration is atypical of New Zealand and Australian mills, and is matched only by other mills also imported from California.

Case Study 6: Homeward Bound Battery, Macetown

The Homeward Bound Battery (site F41/477) is located beside the Richburn, near Macetown in Otago. It is the best example of a text-book stamp mill to be found in the New Zealand goldfields.

The Homeward Bound mill was originally erected as the OPQ Battery at Waipori in 1899 by the OPQ (Waipori) Gold-Mines Limited. In 1910 the New Zealand Consolidated Gold-Mines Ltd purchased the machinery and moved it to Macetown to process ore from the Homeward Bound Mine, but it only operated for a few years before it was abandoned. Both of these companies that owned it were financed from London.

The Homeward Bound battery (Figure 332) is (as already observed) a perfect example of a British-manufactured Sandycroft Foundry ten stamp back-knee frame mill with built-in ore bins, as illustrated in the contemporary literature at the turn of the twentieth century (Louis 1902: 238) (see Chapter 8). When originally erected at Waipori the mill had timber mortar blocks but when re-erected at Macetown it appears that concrete blocks were installed.
Examination of the other technological features of the Homeward Bound indicates that it was an example of contemporary best practice. The mortar boxes are of the ‘Homestake’ pattern, and are the largest recorded during the archaeological survey. They have slotted inclined screens, and have a heavy weight of iron in their bases to accommodate the use of very heavy stamps. The stamps themselves are heavy (with a contemporary reported weight of 1250lb and an archaeologically calculated weight of 1120lb), fitting the trend towards heavier mills led in particular by South African practice. The stamp heads are long (24 inches) but only 9 inches in diameter, supporting the suggestion made in Chapter 8 above that the heaviest mills utilised long but not overly wide stamps in order to increase the pressure exerted at the die. Gib tappets are fitted, and although plain wooden stamp guides are used, this was not unknown in good quality mills. Twin camshafts were fitted, one for each 5 stamps. The camshafts are 6 inches in diameter, a suitable size for the stamp weight. The cams are mounted using Blanton wedges, and one camshaft has right hand cams and the other has left hand cams, to direct lateral thrust from both shafts into the centre battery post. The camshafts were driven from a lineshaft mounted on the cross-sills.

The rockbreaker is present but has fallen into the mill structure (Figure 333), and two automatic Challenge ore-feeders are still in place at the rear of the stamps. At the front of the stamps, gold saving was by amalgamation tables, followed by a Wilfley table. The latter was not mentioned in the published description of the battery in its original location at Waipori (New Zealand Mines Record 1899 Vol. III No. 4), and so was probably added when the plant was moved to Macetown in 1910. A single Berdan was also used.
Figure 333. The rock breaker at the Homeward Bound Battery in 2011.

The Homeward Bound therefore exhibits many of the advanced design features that were available at the end of the nineteenth century, and the use of concrete mortar blocks in its 1910 incarnation but not its 1899 form, together with the addition of a Wilfley table at the same time, is evidence of how contemporary practice continued to be incorporated into its design during its short working life. The presence of a Berdan shows that older technology continued to be used if it was considered effective.

The Homeward Bound Battery supports the argument that British capital often purchased British machinery, and that advanced features were often present on this imported equipment. The lack of wear is also of note, as it indicates that investment in up-to-date technology was not a guarantee of success, and that many other factors were also significant, including the all-important consideration as to whether there were sufficient economic ore reserves to make a mine profitable.

Case Study 7: The Snowy River Battery, Waiuta

The Snowy River Battery (site L31/37) was a large (40 stamp) mill erected beside the Snowy River, near the now-deserted town of Waiuta.

The battery was erected in 1907-1908 by Blackwater Mines Ltd., a subsidiary of the London-based Consolidated Goldfields Ltd. (NZ), to process ore from the Blackwater mine. It was originally constructed as a 30 stamp mill equipped with tube mills, mercury amalgamation, Wilfley tables and a cyanide plant. Power was supplied by a Pelton wheel. In 1924 an Edwards roasting furnace was constructed, and in 1936 a further 10 stamps were added (to bring the total to 40 stamps). However, by the 1930s the plant was recognised as being out of date, and in 1937-38 it was replaced by the new Prohibition Mill (site L31/47) that was both closer to the mine and equipped with more modern tube milling equipment.

Although the battery was demolished and removed, the site retains significant archaeological evidence. The site is arranged down the steep sided valley of the Snowy River in a series of steps. The highest main level is the stamper floor, that contains the timber blocks for the original 30 stamps and the concrete foundation for the 1936 ten stamp addition. Below this are the locations for the tube mills, Wilfley tables and B&M Agitators, and then the lowest level contained the Edwards roaster, Pelton wheel, main cyanide plant and various workshops.
The archaeological evidence provides some important information about the technology employed in the mill. The use of timber stamper blocks for the initial 1907 stamps was acceptable but somewhat old-fashioned for the time, and while the use of concrete for the 1936 addition (Figure 334) was a technological improvement, by this time the use of stamps was out of date. A single loose cam on the site suggests that Blanton cams were used, which is appropriate for a mill of this size and period. Nothing remains of the tube mills, Wilfley tables and Pelton wheels apart from the foundations for their buildings, but again all of these items were up to date technology for the period.

Figure 334. The concrete mortar block for the 1936 ten stamp addition to the Snowy River Battery.

More complete are the remains of the cyanide plant. This consists of 10 sheet iron cyanide tanks (Figure 282 in Chapter 9), one wooden tank (plus the remnants of two others) and two of the original four B&M Agitators (Figure 335).

Figure 335. The B&M Agitators for slimes treatment at the Snowy River Battery.

The Snowy River Battery is therefore a relatively late mill, having worked between 1907 and 1938, and it shows a number of reasonably advanced features, such as the concrete mortar block, Blanton cams and cyanide plant, with a reasonably complex milling circuit. The foundations for the Wilfley and tube mill rooms and the Edwards roasting furnace demonstrate some of this complexity, and set the site apart from simpler mills such as the Young Australian and Homeward Bound. Nevertheless, the Snowy River battery was very out of date as a whole by the time it closed as the use of conventional gravity stamps had been surpassed by tube and ball mills.

What the Snowy River Battery does illustrate archaeologically very well is the use of the cyanide process in larger mills, and in particular the adoption of the B&M Agitator tank that was developed in Waihi. The concrete B&M Agitator tanks at Waihi (site T12/303) are of
greater historical significance than the Snowy River examples, but the latter site places their use and widespread adoption in better context, alongside the conventional open vats and below the identifiable remains of the stamper floor.

Case Study 8: The Bendigo Battery, Waiorongomai

The Bendigo Battery (site T13/90) is located beside the Waiorongomai Stream, in the Kaimai Range. The battery was built in 1910 by the New Zealand-based Bendigo Company (Figure 336), using second-hand machinery from the Hauraki Fortuna Battery near Thames, with the addition of a cyanide treatment plant (Hart 2005: 14). The enterprise was unsuccessful due to the refractory nature of the local ore, and despite several modifications to the battery, including experiments with an oil flotation plant, the mill was finally shut down in 1922. The complete battery stood until 1950, when the building and much of the machinery was removed for scrap.

Figure 336. The Bendigo Battery under construction in 1910. (Auckland Weekly News, Sir George Grey Special Collections, Auckland Libraries, AWNS-19100901-3-3).

The site retains considerable archaeological evidence, including the concrete mill foundations, two mortar boxes and one camshaft, together with all of the cyanide vats, on three levels on the true right of the Waiorongomai Stream (Figure 337).
The remains of the stamp mill represent numerous aspects of typical practice for this period (1910). The mortar blocks and stamp mill foundations are concrete (Figure 338), and the mortar boxes have inclined slotted screen mounts, and were possibly designed for internal amalgamation plates. Both boxes were damaged during the mill demolition, and only one remains on its block. It is embossed ‘A.&G. Price, Makers, Thames, 1896.’ This agrees with the historical information that the machinery was acquired second-hand, and indicates that it was about 14 years old when installed on this site. The surviving 5 cam camshaft (Figure 339) is 5 ½ inches in diameter (which suggests that heavy stamps were used), and the cams have Blanton mounts. They are embossed ‘A.&G. Price,’ which is significant this is the only recorded example of New-Zealand manufactured Blanton cams.

Figure 338. Mortar box on its concrete foundations at the Bendigo Battery site in 2011.
Figure 339. The A.&G. Price camshaft at the Bendigo Battery site in 2011.

The cyanide vats are all corrugated iron (Figure 340), three being 20 feet in diameter and four being 12 feet in diameter. The use of corrugated iron is notable, as this material is light but rigid (Thomson 2005: 15), and is likely to have offered a cost saving over the heavier iron sheet used at sites such as Snowy River (above).

Figure 340. Three cyanide vats at the Bendigo Battery site in 2011.
The Bendigo Battery is particularly significant, as it represents the ‘normalisation’ of many aspects of stamp mill technology in New Zealand. Numerous international developments such as concrete foundations, slotted inclined screens, Blanton cams and the cyanide process were all used, but almost all of the plant was manufactured in New Zealand. Notably, the Bendigo battery has the only confidently-identified locally-manufactured Blanton cams in the country. Local manufacture of this type of design feature indicates that not only has it been imported, but consciously adopted by the local industry.

**Discussion of Case Studies: Macro- and Micro-Innovation**

These eight case studies illustrate how a series of different mills, despite all superficially being examples of the ‘micro-innovation’ (Burt 2000) or ‘regional hybrid’ (Limbaugh 1998) Californian Stamp Mill, show a wide variety of different influences and design features. The Young Australian Battery with its early-1870s machinery is a very different beast to the Bendigo Battery and its 1890s machinery, despite the fact that both were gravitational stamp mills manufactured in New Zealand, and the Eureka Battery is very different to all of the other examples as although it shows up to date technology, its configuration is only found in other Californian-made examples. Therefore, rather than considering the stamp mill as a single micro-innovation that emerged in 1850s California, it is better to regard it as a series of micro-innovations, and any single example will exhibit a different mix of specific design details. The rest of the milling circuit exhibits a similar tendency. The basic processes of gravity separation and mercury amalgamation continued to be important throughout the period concerned, but with a constantly changing mixture of other general processes and particular designs being adopted and used. The macro-/micro-innovation model can be applied to a number of the design features discussed in these case studies, to consider how they changed over time, and how the various parts of the battery were inter-related.

The frame is the most notable element of any stamp mill, and the case studies illustrate a continuum from the perfect example of an international heavyweight design (the Homeward Bound Battery) to the lightweight A-frame (Young Australian) that is well-represented archaeologically, but poorly-represented in the contemporary literature. Variations include the American four post frame (Eureka), and the cast iron frame (Albion). This variety illustrates the range of smaller mill designs that existed but were not necessarily discussed in the contemporary literature, and how the larger (and heavier) New Zealand mills did largely conform to international designs.

Despite representing what could be termed an ‘engineered approach,’ the cast-iron frame is not necessarily an indication of a technically advanced mill, and the Albion exhibits resolutely conventional technology, a characteristic that it shares with other similar mills such as Anderson’s (site F41/473) and the Golden Lead (site L31/29). Neither did iron displace the timber frame, which remained the material of choice for the heaviest mills due to its resilience; the wooden Homeward Bound and Nugget frames both post-date the iron Albion, and the 200 stamp Victoria Battery (site T13/300) was timber-framed. Conversely, concrete did gain acceptance as its rigidity worked well for foundations, and the Snowy River and Homeward Bound illustrate the progression in the use of this material.

The mortar box is at the heart of the battery, and the case studies illustrate the evolution of this item from the 1860s until the 1900s. The earliest boxes at the Nugget Battery had multiple outlets and vertical bolt-on screens. The multiple outlet pattern rapidly fell out of
favour, as seen at the Nugget by the blanking over of the side and rear outlets and the later replacement of the boxes with simpler single-outlet items. However, the triple-outlet pattern persisted in small numbers for a long period, particularly in imported American mills as illustrated by the Eureka Battery. The evolution of screen mounting can be seen in the change from vertical bolt-on mounts (e.g. the 1871 Young Australian machinery) to the inclined slot (e.g. the 1896 Bendigo machinery), with the Nugget Battery illustrating the change at a single site.

The case studies support the idea that stamp weight generally increased over time, and they show a general continuum from the lightweight Young Australian (566 lb) and Albion (480 lb) mills of the 1870s to the heavyweight Homeward Bound (1030 lb) of 1899. The associated tappet designs show a similar evolution, with the plain collar tappet of the Young Australian and screw tappet of the Albion replaced by the gib tappet of the Nugget, Eureka and Homeward Bound. The earlier forms were not only prone to wear, they were not suitable for the ever-increasing stamp weights of the developing mill design. The mixture of tappet types at the Phoenix/Achilles is evidence of a mill staying in service for a long period of time with periodic upgrades, but presumably with a mixture of parts of all ages remaining in use.

The introduction of the Blanton cam is a very useful chronological marker amongst the micro-innovations, as its patent date of 1893 is known. It is correspondingly absent from all earlier mills, but appears rapidly in the Bendigo (1896 machinery), Homeward Bound (1899 machinery), Eureka (1906) and Snowy River (1907) batteries. The latter three of these mills used imported machinery, but the presence of the A.&G. Price manufactured Blanton cams at the Bendigo Battery shows that the technology had been actively (and rapidly) adopted in New Zealand as well as merely imported.

The firm of A.&G. Price of Thames also held the New Zealand rights to the Pelton wheel (gained in 1884), another innovation with known patent date (1880). This was a micro-innovation from earlier impulse wheels, but was significant that it rapidly displaced many other forms of turbine, and therefore had a major impact. The Young Australian water wheel was abandoned where it stood once the Pelton wheel became available, and amongst the case study examples only the Albion (steam power) and Eureka (oil engine) were not at some stage powered by a Pelton wheel. The Pelton in turn played a key role in the development of hydroelectric power at Bullendale, which heralded a whole new industrial age.

Electric power was a macro-innovation of significance to a much wider audience that just the mining industry, although it was mining that took the lead in New Zealand until about 1913, searching out and importing from overseas up-to-date equipment and technology (Petchey 2013). The pioneering work at Bullendale in 1885/1886 by the Phoenix Company is interesting as the archaeological evidence of the battery itself shows the use of quite old-fashioned milling technology. This suggests that the process of technological development was not simple and linear; at the Nugget Battery the 1903 rebuild swept away the earlier mill, but at Bullendale the application of new technology was married to the existing plant.

The adoption of the cyanide process is another example of a macro-innovation that was introduced at a known date (1889), and was then subject to an on-going process of micro-innovation. The original 1889 timber vats (now only surviving at Ferguson’s New Era Works) were followed by circular sheet iron tanks, circular corrugated iron tanks, and the tall thin B&M Agitator tanks (in both iron and concrete). Not all mills used the process, and no two plants were identical, although all shared the same basic chemical approach. The use of
corrugated iron for the tanks at the Bendigo site is notable as it provides a link between mining technology and the ubiquitous building material of colonial New Zealand (see Thomson 2005). With its combination of New-Zealand manufactured Blanton cams and other machinery, concrete foundations and corrugated iron tanks, the Bendigo Battery represents the ‘normalisation’ of much international technology into a New Zealand setting.

The eight case study examples therefore present a complex mixture of macro-innovations, micro-innovations and subsequent micro-innovations, which created a range of machines that were all nominally the same device, but no two of which were actually the same. To explain how these developments either came to New Zealand, or happened within New Zealand, it is necessary to examine some of the influences and agents involved.

**Agency & Influence in Technology Transfer**

The Californian Mill did not simply emerge in California in the 1850s and then get transported around the world, to appear in New Zealand as a fully-formed machine. There was a continuing process of change and innovation that accompanied the mill, with a complex web of international and local agents and influences that created that change. These factors were many and varied, and included the natural world (geology, environment, distance), human agency (personal knowledge and experience), information flow (transport, communications, publications), government (mining regulations, the Schools of Mines, mines inspectors), machinery manufacturers (local and overseas) and the business world (foreign capital and overseas management decisions). Any or all of these factors could interact with each other to influence anything from a large mining field to an individual mining venture, and together form a ‘sociotechnical system’ of enormous scope and complexity (Hughes 1983; Pfaffenberger 1998: 296).

**Geology**

Geology underlies all mining enterprises, as gold mining can only successfully occur where gold is present. As briefly discussed in Chapter 3, sulphide ores (pyrites) in particular could interfere with gold recovery, causing large amounts of gold to be lost in the tailings. Early quartz mines generally worked shallow reefs with oxidised ores that were reasonably free-milling, but as the mines got deeper the sulphide ores were encountered: “the deeper the mines are worked, the more solid and intractable the pyrites are likely to become” (Otago Witness, 11 July 1885: 3, commenting on the Wakatipu mines). Some fields, such as Karangahake and Waiorongomai, had notoriously refractory ores from the outset.

As the loss of gold through a battery could be determined by comparing assay results with battery returns, much effort was directed at improving gold recovery processes. Developments such as vanners, furnaces, the Wilfley table, chlorination and cyanidation were all wholly or partly in response to the difficulties posed by refractory ores. At Karangahake, where the cyanide process was first trialled in New Zealand in 1889, earlier experiments with various furnaces had been failures, and despite some reticence based on these earlier bitter experiences, the new process was readily adopted once it proved successful. At Waihi the Waihi Mining Company was profitable for so long because it successfully applied the latest extraction technology to the large but low-grade ore body. Experiments there also helped improve the science, as seen in the development of the B&M Agitator that could successfully treat slimes with cyanide.
Environment

Environmental determinism is unfashionable (Limbaugh 1998: 25), but a large degree of environmental influence is clear in the archaeological record. In particular, many New Zealand hard rock goldfields are in mountainous country, and this challenging terrain led to many adaptive responses. The use of sectional mortar boxes was one such response, as these boxes could be dismantled for ease of transport. Despite their acknowledged propensity to work loose and leak these boxes were widely adopted, possibly the best examples being at the Phoenix/Achilles and Southberg’s batteries, both deep in the Harris Mountains.

The availability of water at elevation was a critical consideration as a source of power. The Pelton wheel was a development from the American west coast mountains, where low-flow but high-head water supplies were commonly available and it proved ideal for New Zealand’s similar conditions. The archaeological evidence confirms that it was widely adopted after its introduction in 1884. The same mountainous conditions and water supply issues persuaded George Bullen and Fred Evans to investigate the installation of the hydro-electric scheme at Bullendale in 1885/1886 to power their battery. The power line across Southberg’s Spur demonstrated how electricity could not only be transmitted over distance, but also across mountainous terrain. Environmental constraints have therefore not only influenced the technology that was imported to New Zealand, they also encouraged innovative adaptation of that technology to suit local conditions.

Transport & Communication

Transport and communication networks were essential for the dissemination of technology, either as abstract information, experienced people, or physical machinery. It was Britain’s good internal transportation networks that allowed technology to spread rapidly during the Industrial Revolution, and the same rule applied as technology moved globally (Gaughwin 1992: 56; Mokyr 1990: 246; Pryor 2011: 89, 156). European settlement of New Zealand could only occur in a period when long-distance travel had become well established, and as Andrews (2009: 300) has observed, this relative ease of movement meant that New Zealanders could readily borrow from other cultures, especially Britain, the United States and Australia. The time it took people, books and information to travel internationally steadily decreased in the latter decades of the nineteenth century, particularly once efficient steamships came into widespread use. An immigrant voyage between Britain and New Zealand in the late 1850s generally took 110 to 130 days, but by the 1880s a run by the Shaw Savill steamer *Arawa* had cut this to 38 days (McLean 2001: 61-62, 96, 101). The potential time lag for both information flow and importation of equipment was therefore as little as one to two months from Britain, and the west coast of America was even closer. International telegraphic communication began for New Zealand in 1876 when the first telegraph cable from Australia came ashore near Nelson (Lewis 2012), and the ability to rapidly transmit mining and commercial information was an important factor in the overseas investment in New Zealand mines in the 1880s and 1890s.

The first ‘engineered’ mining machinery used in the New Zealand goldfields came across the Tasman Sea from the Melbourne foundries of A.K. Smith (Carlton Foundry) and Langlands & Co. in the 1860s. Later Australia, Britain and America continued to be sources of machinery, and the British and American plant often included improved technology. The
weight of machinery was not necessarily a problem for international shipping, as sailing ships required ballast, and heavy cargoes could be carried long distances very economically.

Once machinery was landed in New Zealand (or manufactured locally), internal communications in the relatively undeveloped colony could prove to be a greater challenge than the international voyage. The mines inspector reported in 1881 that a ten head battery which cost less than £1000 to erect near Thames would cost about £4000 around Reefton, mainly because of the transport costs (Wright 2004: 15). Lack of access was a common complaint of mining companies, and they often looked to the government to construct roads to assist the development of goldfields. Today the best-known of these roads is the Skippers Road in Otago that was constructed between 1882 and 1890, and now provides access to a number of popular tourist attractions in the Shotover Valley.

**Government**

The Government was an active agent of goldfields and technological development. As discussed in Chapter 4 above, the New Zealand goldfields benefitted from having an already established authority, and local mining regulations were developed with the knowledge of the Australian experiences without having to repeat the same mistakes (Fetherling 1997: 78). The Government through the agency of the Minister of Mines and the Mines Department also employed mining experts (H.A. Gordon being the best known), developed roads and infrastructure, and published industry-specific literature. Government acted generally to encourage mining, as it was seen as positive economic development, and one of its most significant single actions was the purchase in 1897 of the local rights to the cyanide process. The large number of post-1897 cyanide plants that survive in the archaeological record are testament to the effectiveness of this action. Roads such as the Skippers Road, tramways such as the Piako County Council tramway at Waiorongomai, the Schools of Mines (discussed below) and Government Batteries such as the Coromandel Government Battery all show how Provincial, Central and local government acted as active agents of mining development.

**People**

From the very outset the New Zealand goldfields were influenced by the international experience of the miners. Many of the New Zealand residents that flocked to the new goldfields were born elsewhere, and these locals were rapidly outnumbered by new immigrants. In Otago the population rose from 12,691 to 30,269 in the 12 months to December 1861, and immigration flows peaked at over 45,000 people in 1863 (OPC V&P Session XVI 1862: 17; Phillips & Hearn 2008: 38). As discussed in Chapter 4, many of the key discoveries and developments were made by those with specific overseas mining experience.

Australia was the obvious place for miners and millmen to gain experience due to its proximity and already established mining industry, and in the rushes of the 1860s the clear majority of miners came from across the Tasman (Phillips & Hearn 2008: 38). Australia was also the source of the earliest manufactured milling machinery, and continued to be a supplier of basic equipment, and people were part of this process. A.K. Smith of the Carlton Foundry, Melbourne, visited New Zealand and personally advised early mining ventures on the equipment that he could supply (Daily Southern Cross, 8 July 1862: 3). Probably the oldest surviving stamp mill component in New Zealand, the Victory water wheel
(site H44/61) at Waipori, was manufactured at Smith’s foundry. Other examples of Australian experience and expertise are common; for example, when describing the early quartz reef discoveries at Macetown in Otago, Warden Stratford compared the stone to that found at Sandhurst, Inglewood and Statwell, Victoria (AJHR 1876 H3: 4).

However, even amongst the immigrants coming from Australia, many of these people had their origins elsewhere (Phillips & Hearn 2008: 38, 57). Much has been written about the influence of various national groups on mining history, in particular the Cornish miners that left their homeland in the nineteenth century as the local tin mining industry declined, and carried with them extensive experience of hard rock mining practices (eg. Blainey 1993: 46; Bolitho 1999: 11; Landon & Tumberg 1996; Reynolds 1974). Cornish miners were certainly present and influential in the New Zealand goldfields; for example, Cornishman John Trennery was involved in a number of quartz mining ventures around Reefton, including Anderson’s Creek and the Ajax, and he was instrumental in introducing compressed air rock drills to the area in 1881 (Bolitho 1999: 25; Hutchison 2004; Latham 1984: 352). In America, Landon & Tumberg (1996) found direct archaeological evidence of Cornish milling practices used by Cornish miners at the Ohio Trap Rock Mine Site, in the form of round Cornish buddles associated with a stamp mill. However, the only substantial remaining buddle in New Zealand, the Otago Pyrites Saving Company’s example (site E40/59) associated with the Invincible Mine, was manufactured in Germany and operated by W. Dickenson who trained as an ore dresser at the Mount Bischoff Mining Company in Tasmania (Otago Witness, 27 August 1886: 12). This underlines the international nature of much technology, but also the need for caution when making assumptions about particular national associations.

It is clear from both the archaeological and historical records that many nationalities were represented, and while it is easy to make a broad statement that international experience led to the adoption of international technology, it is harder to find direct links between individuals’ home countries and archaeological evidence of milling technology specific to that country. For example, the Reefton mines were heavily influenced by a number of immigrants from places other than Australia, Britain or America, including the Italian Gerald Perotti and the Lithuanian entrepreneur David Ziman.

David Ziman was the most influential single person in the Reefton goldfield, and is an example of the promoters and entrepreneurs that acted as conduits between the mines and overseas (particularly London) capital. He grew up in London and gained his mining and stockmarket knowledge in South Africa, and is credited with reviving Reefton’s flagging fortunes (Latham 1984: 389-397; Bolitho 1999: 45). In this case it was his combination of mining knowledge and business skills that were of particular importance, and he was instrumental in setting up the London-based Consolidated Goldfields of New Zealand Ltd. in 1896. This company revitalised local mining, and amongst other developments built (through a subsidiary company) the Snowy River Battery.

What is significant about many mining experts is therefore probably not where they came from, but the fact that they often continued to travel widely between gold fields with the specific aim of studying mining technology to improve their own operations or to raise funds to float new enterprises. For example, in about 1886 J. Adams, manager of Messrs. Firth and Clarke’s battery at Waiorongomai travelled to California to study the different extraction processes for gold and silver, taking samples of stone with him to test the various methods (AJHR 1887 C5: 66). The government also sent their experts overseas, and in 1884 H.A. Gordon, the Mines Department’s Mining Engineer, was sent to Australia to report on gold
mining techniques being used there (Salmon 1963: 214). He then co-operated with Hector and Patrick Galvin in the preparation of the 1887 *Handbook of New Zealand Mines*, followed by the publication of his own *Miners’ Guide* in 1889 (followed by two subsequent editions; Gordon 1894, 1906).

It therefore is apparent that while some expertise was definitely carried from specific places such as Cornwall to New Zealand, the overall picture was complex and involved the continuous movement of people between many different mining fields, who took different levels of knowledge and expertise with them, and then disseminated that knowledge and/or made decisions based on it. Menghetti (2005: 204) summed up this complicated process by stating that “miners and mining equipment moved, and still move, around the world with an insouciance unmatched in other industries,” and the archaeological record reflects this complexity.

**Technical Literature**

A third way for technology to travel was through the medium of technical literature, which has already been reviewed in Chapters 2, 5 and 6 above. This literature was typically held by individuals (generally those employed in the mining industry), by athenaeums, and by Schools of Mines.34 The specific histories of some of these books can be of interest, as this can show that particular technical information was available at a particular place and time.35 For example, a copy of Henry Louis’ (1902) *A Handbook of Gold Milling* held by Bill Watts of Black’s Point near Reefton was originally owned by Edgar Elliston (Figure 341), a local miner and millman, who died in 1978 at the age of 90 (Reefton Cemetery Records, [http://public.bullerdc.govt.nz](http://public.bullerdc.govt.nz)). Elliston had earlier given the book to Bill Watts’ father, Colin Watts, who was one of the party that re-opened Bolitho’s old cement mine and battery at Lankey Creek (site L30/174) in the 1930s. The book was later used extensively as a reference when the reconstructed battery at Black’s Point Museum (Figure 342) was being erected in the 1970s (W. Watts, pers. comm. 2011). It is therefore certain that the information presented by Louis (1902) was available and being used around Reefton for most of the twentieth century.

![A Handbook of Gold Milling](image)

**Figure 341. Title page of a copy of Louis (1902), originally owned by Edgar Elliston.**

---

34 It is almost certain that some companies would also have had technical libraries, but definitive evidence of this in the form of surviving marked books was not found.

35 It is therefore reasonable to consider these historic books to be archaeological artefacts in their own right, as well as works of reference.
Figure 342. The reconstructed stamp mill at Black’s Point Museum.

The various Schools of Mines around the country held libraries of varying sizes. None now survive intact, but partial original collections are still held in the old Schools of Mines buildings at Coromandel (now the Coromandel Mining & Historic Museum), Thames, and Reefton and in the Otago University library. The latter is the largest collection, despite the loss of much material in 1986 when the last functions of the School closed, and includes numerous runs of industry journals from the 1870s onwards. Many of these journals were used in the research for this thesis.

Schools of Mines

Schools of Mines had two basic functions; to educate mine managers, battery superintendents and other professional staff to the point where they could sit their certification exams; and to provide a more general mining-based education to the miners. They therefore played an essential role in the dissemination of technical knowledge throughout the goldfields.

The first school of mines was the Freiberg Mining Academy in Saxony in 1764, and was followed by others at Nancy in France, St. Petersburg and Leningrad in Russia, and at Almaden in Spain (Bolitho 1999: 9-10). The Royal School of Mines and Museum of Practical geology was opened in London immediately after the Great Exhibition of 1851, and in 1859 the Miners’ Association of Cornwall and Devon was formed and began to operate travelling schools. From the 1880s full-time schools began at Truro, Camborne, Redruth and Penzance, which were amalgamated at Camborne in 1909 (Bolitho 1999: 11). From Europe and Britain the Schools of Mines Movement spread around much of the world in the late nineteenth century.

When the University of Otago was established in 1869 the first Professor of Natural Science, James Gow Black, had extensive mining experience, and when the Otago School of Mines (Figure 343) opened in 1879 Professor G.H.F. Ulrich was appointed as its first director (Bolitho 1999: 33; Parry 1979: 1). The establishment of numerous small provincial Schools throughout the goldfields began in 1884 when Professor Black gave three lectures at the Lawrence Athenaeum and Mining Institute (Galvan 1887: Appendix; Twohill 1999: 249). As a result of the enthusiasm that greeted these lectures, Professor Black was engaged the following year to undertake a travelling lecture series for miners in the West Coast and Otago goldfields (AJHR 1888 C5: 7; Salmon 1963: 215). He met with enthusiastic receptions everywhere he went, and a system of Schools of Mines was set up across the goldfields in
both main islands, with the buildings and equipment provided by government subsidy (Salmon 1963: 215).

Figure 343. The original building of the Otago School of Mines.

The next Schools to be established in New Zealand were at Reefton and Thames in 1885 (Figures 344) (Bolitho 1999: 34; Twohill 1999: 249; Weston 1927: 225), and these two schools are now notable as they survive today (2013) as the two best preserved schools of mines in New Zealand (Figure 345).

Some of the smaller schools were little more than rooms with a small technical library and some geological specimens, but other schools were well-equipped to teach all aspects of mining. For example, the Thames School of Mines had an experimental battery consisting of a rock-breaker, self-feeder, three stamp battery, Berdan, cyanide plant, retorting furnace and assay plant, as well as a library, lecture room, assay room, public room, geological museum, electrical laboratory and machine shop (Weston 1927: 225-227). The school was active in promoting the cyanide process, and the battery plant was extensively used by the Unemployment Board’s subsidised prospecting schemes during the 1930s Depression (Twohill 1999: 252).
As the fortunes of various mining fields fluctuated schools opened and closed. The closure of the Martha Mine at Waihi in 1952 was a major factor in the closure 2 years later of the Thames School of Mines (Twohill 1999: 252). In 1964 the Otago School of Mines was restructured as a smaller Department of Mineral Technology, and this was itself transferred
north to Auckland in 1986 bringing to an end the Schools of Mines in New Zealand (Parry 1979; NZHPT Register, No. 4771).

**Machinery & Machinery Manufacturers**

The most direct way for technology to be brought to New Zealand was by importing machinery, and there is ample archaeological evidence for machines made in Australia, Britain and America, with a small amount of German equipment also present. Machinery made in New Zealand can show how imported technology was adopted and adapted locally, and identification of the local manufacturing companies can determine which were innovative and which merely produced conventional equipment. Table 50 lists local and overseas manufacturers that have been identified from the archaeological record.

**Table 50. Manufacturers of battery machinery.**
*(In 2 parts, see also next page)* Based on surviving makers’ marks and makers’ plates. This list does not include just stamps, but also associated plant such as rockbreakers and ore feeders. Date (a) is the date of manufacture when known, and Date (b) is the date of installation at the present site.

<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Manufacturer</th>
<th>Country</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Allis Chalmers Co. Milwaukee</td>
<td>USA</td>
<td>1911</td>
<td>1911</td>
</tr>
<tr>
<td>Rise &amp; Shine</td>
<td>G41/277</td>
<td>Askham Sheffield (tappets)</td>
<td>England</td>
<td>1939</td>
<td></td>
</tr>
<tr>
<td>Unprovenanced (at Victoria)</td>
<td></td>
<td>Bowes Scott &amp; Western, London</td>
<td>England</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victory (water wheel)</td>
<td>H44/61</td>
<td>Carlton Foundry, Melbourne</td>
<td>Australia</td>
<td>1863</td>
<td>1875?</td>
</tr>
<tr>
<td>Nugget</td>
<td>F41/23</td>
<td>Cossens &amp; Black</td>
<td>New Zealand</td>
<td>1903</td>
<td>1903</td>
</tr>
<tr>
<td>Kirwan's Reward/Lord Brassey</td>
<td>L30/62</td>
<td>Dispatch Foundry, Greymouth.</td>
<td>New Zealand</td>
<td>1900</td>
<td>1902</td>
</tr>
<tr>
<td>Cherry &amp; Sons (cams)</td>
<td>T13/294</td>
<td>F &amp; C Ltd.</td>
<td>England (or USA)</td>
<td>1932</td>
<td></td>
</tr>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Fraser &amp; Chalmers Ltd.</td>
<td>England</td>
<td>1898</td>
<td>1898</td>
</tr>
<tr>
<td>Taitapu</td>
<td></td>
<td>Fraser &amp; Chalmers Ltd.</td>
<td>England</td>
<td>1896</td>
<td>1897</td>
</tr>
<tr>
<td>Government Battery (1 stamp box)</td>
<td>T10/1115</td>
<td>Fraser &amp; Tinne</td>
<td>New Zealand</td>
<td>1899-1900</td>
<td></td>
</tr>
<tr>
<td>Sawyer's</td>
<td>T12/1411</td>
<td>Fraser &amp; Tinne</td>
<td>New Zealand</td>
<td>1938</td>
<td></td>
</tr>
<tr>
<td>Printz</td>
<td>D46/150</td>
<td>Fraser &amp; Tinne</td>
<td>New Zealand</td>
<td>1880</td>
<td></td>
</tr>
<tr>
<td>Eureka</td>
<td>E41/51</td>
<td>Hendy, Joshua</td>
<td>USA</td>
<td>1905</td>
<td></td>
</tr>
<tr>
<td>Red Queen</td>
<td>L28/24</td>
<td>Hendy, Joshua</td>
<td>USA</td>
<td>1885?</td>
<td></td>
</tr>
</tbody>
</table>

---

36 The Otago Pyrites Company buddle and other plant was described as being of German manufacture, but the actual maker was not recorded (*Otago Witness*, 27 August 1886: 12).
<table>
<thead>
<tr>
<th>Site</th>
<th>NZAA No.</th>
<th>Manufacturer</th>
<th>Country</th>
<th>Date (a)</th>
<th>Date (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauraki Prospectors Assn.</td>
<td></td>
<td>Judd, Chas.</td>
<td>New Zealand</td>
<td>1900</td>
<td>Modern</td>
</tr>
<tr>
<td>Serpentine</td>
<td>H42/2</td>
<td>Kincaid &amp; McQueen</td>
<td>New Zealand</td>
<td>1878?</td>
<td>1890</td>
</tr>
<tr>
<td>Phoenix (rockbreaker)</td>
<td>E40/40</td>
<td>Kincaid &amp; McQueen</td>
<td>New Zealand</td>
<td>1885</td>
<td>1885</td>
</tr>
<tr>
<td>Mercury Bay Museum</td>
<td></td>
<td>Langlands &amp; Co.</td>
<td>Australia</td>
<td>1907</td>
<td></td>
</tr>
<tr>
<td>Johnston's United (RH battery)</td>
<td>M25/73</td>
<td>Langlands Foundry</td>
<td>Australia</td>
<td>1870s</td>
<td>1879</td>
</tr>
<tr>
<td>Black's Point Museum</td>
<td></td>
<td>Langlands Foundry</td>
<td>Australia</td>
<td>1972-1976</td>
<td></td>
</tr>
<tr>
<td>Wellington</td>
<td>O28/47</td>
<td>Langlands Foundry</td>
<td>Australia</td>
<td>1870s</td>
<td>1901</td>
</tr>
<tr>
<td>Hauraki Prospectors Assn. (prob. ex Victoria)</td>
<td></td>
<td>Martha Gold Mining Co.</td>
<td>New Zealand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waimea</td>
<td>M28/5</td>
<td>Masefield &amp; Co. Auckland.</td>
<td>New Zealand</td>
<td>1870</td>
<td></td>
</tr>
<tr>
<td>No. 2 South Larry's</td>
<td>L30/7</td>
<td>Moutray, Nelson</td>
<td>New Zealand</td>
<td>1874?</td>
<td>1892</td>
</tr>
<tr>
<td>Cosmopolitan</td>
<td>H44/745</td>
<td>Otago Foundry</td>
<td>New Zealand</td>
<td>1876</td>
<td>1917</td>
</tr>
<tr>
<td>Arethusa</td>
<td>D46/161</td>
<td>Otago Foundry, Dunedin</td>
<td>New Zealand</td>
<td>1887</td>
<td></td>
</tr>
<tr>
<td>Battery Creek</td>
<td>T12/1410</td>
<td>Pacific Iron Works, S.F.</td>
<td>USA</td>
<td>1889</td>
<td>1899?</td>
</tr>
<tr>
<td>Bonanza (Huntington Mill now at Golden Point)</td>
<td></td>
<td>Parke &amp; Lacy (Sydney)</td>
<td>Australia</td>
<td>1889</td>
<td>1894</td>
</tr>
<tr>
<td>Callery’s (rock breaker)</td>
<td>I42/161</td>
<td>Parke &amp; Lacy (S.F.)</td>
<td>USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Britannia (ore feeder)</td>
<td>L29/15</td>
<td>Parke &amp; Lacy (Sydney)</td>
<td>Australia</td>
<td>1929</td>
<td></td>
</tr>
<tr>
<td>Luck at Last</td>
<td>T12/601</td>
<td>Pelton Water Wheel Co.</td>
<td>USA</td>
<td>1899</td>
<td></td>
</tr>
<tr>
<td>Government Battery (5 stamp box)</td>
<td>T10/1115</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1899-1900</td>
<td></td>
</tr>
<tr>
<td>Golden Lead</td>
<td>L31/29</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1891</td>
<td></td>
</tr>
<tr>
<td>Golden Blocks</td>
<td>M25/81</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1899</td>
<td>1899</td>
</tr>
<tr>
<td>Bickerton's</td>
<td>I43/136</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1896</td>
<td>ca 1913</td>
</tr>
<tr>
<td>Bendigo</td>
<td>T13/90</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1896</td>
<td>1910</td>
</tr>
<tr>
<td>Britannia (mortar box)</td>
<td>L29/15</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1929</td>
<td></td>
</tr>
<tr>
<td>United Goldfields (RH box)</td>
<td>F41/484</td>
<td>Price, Thames</td>
<td>New Zealand</td>
<td>1898</td>
<td>ca. 1916</td>
</tr>
<tr>
<td>Homeward Bound</td>
<td>F41/477</td>
<td>Sandycroft Foundry</td>
<td>England</td>
<td>1899</td>
<td>1910</td>
</tr>
<tr>
<td>Anderson's</td>
<td>F41/473</td>
<td>Sparrow &amp; Co., Dunedin</td>
<td>New Zealand</td>
<td>1907</td>
<td></td>
</tr>
<tr>
<td>Ajax</td>
<td>L30/31</td>
<td>Union Foundry, Ballarat</td>
<td>Australia</td>
<td>1871</td>
<td>1871</td>
</tr>
<tr>
<td>Welcome Jack</td>
<td>T11/693</td>
<td>Union Iron Works, S.F.</td>
<td>USA</td>
<td>1900</td>
<td></td>
</tr>
<tr>
<td>Canvastown monument</td>
<td></td>
<td>Union Iron Works, S.F.</td>
<td>USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coromandel School of Mines</td>
<td></td>
<td>Union Iron Works, S.F.</td>
<td>USA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As discussed above, Australia was the earliest source of ‘engineered’ mining machinery in the New Zealand goldfields. Victoria’s gold mines were the main-stay of the local engineering industry (Blainey 1993: 59), and this industry was the first port of call when New Zealand’s fledgling quartz mines required machines. The first machinery came from the Melbourne foundries of A.K. Smith (the Carlton Foundry) and Langlands & Co., and Australian machinery continued to be imported into New Zealand. Langlands & Co. in particular remained a supplier of generally conventional machinery (Table 50). As discussed in Chapter 8, the ‘Australasian’ iron-framed battery was manufactured by both Australian and New Zealand companies, and tended to exhibit very conservative engineering.
American manufactured equipment mainly came from San Francisco, with just one machine (the Golden Blocks battery) from Milwaukee. By the mid-1860s San Francisco had more than 40 manufacturing plants turning out mining machinery, supplying both local and overseas markets (Limbaugh 1998: 41), and Joshua Hendy’s Machine Works, the Union Iron Works and the Pacific Iron works all supplied machines that survive in New Zealand. The firm of Parke & Lacy, established in 1874, had foundries in both San Francisco and Sydney (http://searchworks.stanford.edu/view/9334091; Sydney Morning Herald, 7th January 1926: 11), and machinery from both of these locations has been found. As discussed in Chapter 8, most of the American equipment identified in the survey was very different in form to the New Zealand, Australian and British machines. The three main US types; the 2 post 2 stamp prospectors’ mill, the 2 stamp triple discharge 4 post mill, and the 5 stamp 4 post iron mill with fully sectional mortar box; form a distinct subset. Only the more conventional Allis-Chalmers mill from Milwaukee resembles mills from other countries.

The surviving English equipment comes from four main companies; The Sandycroft Foundry of Chester, Fraser & Chalmers Ltd., Bowes Scott & Western Ltd. of London and Askham Brothers & Wilson. Fraser & Chalmers was an Anglo-American company, with plants in Chicago and London (NZMR 16 October 1897), but it is the British manufactured equipment that appears to be present in New Zealand (see Table 50). The surviving British machinery tends to be heavy (with the exception of the small Golden Blocks prospecting stamper), and up-to-date. The Taipatu and Homeward Bound mills in particular are exemplary examples of battery engineering for their period.

New Zealand manufacturers are well represented in the archaeological record. Possibly the oldest surviving machine is the Fraser & Tinne 6-stamp machinery at Printz’s Battery (site D46/150) (Figure 346) in Southland that was moved from the Coromandel in 1879 (AJHR 1880 H26: 31). George Fraser and Theodore Tinne established the Phoenix Foundry in 1867 and supplied heavy machinery to the Coromandel goldfields (Figure 347), and their 6-stamp machine erected at Kuranui Battery in November 1867 was regarded as the first efficient mill on the Thames field (Macready et al 2013:170; Ritchie 1990: 99; Thames Miners’ Guide 1868: 93). Printz’s Battery matches the contemporary description of the Kuranui mill, and shows some anachronistic features such as the use of timber upper sections to the mortar boxes (see discussion in Chapter 8), and is probably a similar pattern and age as the Kuranui mill.

Figure 346. The Fraser & Tinne 6 stamp mill at Printz’s Battery (site D46/150).
There were a large number of other local manufacturers, with particular concentrations near the main goldfields. Dunedin had a number of foundries that serviced the Otago goldfields, and the city became internationally renowned for its role in the development of gold dredge technology (Hearn & Hargreaves 1985; May 1969: 72). Important manufacturers represented in the archaeological record include Kincaid & McQueen, Cossens & Black and the Otago Foundry. Greymouth has the Dispatch Foundry (still in existence as Dispatch & Garlick Ltd.), well-known for its bush locomotives and other timber milling plant as well as gold mining equipment. The recently-restored Kirwan’s Reward Battery near Reefton is the best surviving example of a Dispatch battery. Moutray & Co. in Nelson also supplied the Reefton goldfield, and manufactured the surviving No. 2 South Larry’s Battery in 1873 (Grey River Argus, 27th July 1874: 2).

Machinery manufacturers therefore acted as agents for the introduction of new technology, but their effects were variable. British and American machinery was the most likely to have up-to-date innovative features, while Australian machinery, despite its head start in New Zealand, was most likely to be conservative. New Zealand manufacturers also tended towards conservatism, but did adopt general good practice over time (the Nugget Battery described in detail above is a good example). When discussing gold batteries at Bendigo, Victoria, Rickard (1898: 147) observed that foundries tended to be conservative in order to change their patterns as seldom as possible, and this is borne out by the field evidence. However, A.&G. Price of Thames stand out as early adopters, as that firm incorporated new technological developments quickly, and these products were widely disseminated.
International Capital

It was never cheap to develop a quartz mine and build a stamp mill; at the very beginning of hard rock mining in New Zealand the value of the imported OPQ plant at Waipori was listed as £1200 (OPC V&P 1864 Session XIX: 6). Twenty years later in 1883 the 10 stamp Croesus Battery (site L29/2) then under construction was valued at £1,800 (AJHR 1883 H5: 30). By the 1880s, when much of the easily processed gold had been worked out and there was the need for more expensive machinery, British attention had turned to the potential of the mining industry, and much of the investment in new plant was paid for by overseas syndicates. The role and influence of overseas finance was discussed above in Chapter 4, and the flow of money into fields such as Waihi, Reefton and Macetown was described. In many cases local promoters, such as David Ziman at Reefton and W.J. Farrell at Macetown, were inseparable from the process, and acted as the conduit between capital and mine.

Some excellent archaeological examples of the influence of these overseas companies survive in the goldfields. The Snowy River, Homeward Bound, Taipatu and Victoria batteries were all large and made use of many contemporary technological developments. The most intact surviving example is the 10 stamp Homeward Bound battery at Macetown. When the mill was first erected at Waipori in 1899 the London syndicate OPQ (Waipori) Gold-mines (Ltd) spent “an enormous amount of money in developing the mine and procuring very costly machinery” (AJHR 1899 C3A: 63; 1902 C3: 120), and then in 1910 its move to Macetown was also paid for by London finance.

Glaswegian finance also played a significant role in New Zealand, particularly in the establishment of the cyanide process. The first cyanide plant in New Zealand was set up at Karangahake in 1889 by the Glasgow-based Cassel Gold Extraction Company to process ore from the Crown Mine, and the New Zealand Crown Mines Company had been floated in Glasgow in 1888 by Thomas Melville. Melville also assisted Peter Ferguson of the New Era Syndicate at Waiorongomai to gain the backing of a ‘Glasgow syndicate’ and erect a Cassel cyanide plant in 1889 (Auckland Star, 11 February 1889: 3; Te Aroha News, 1 May 1889: 2). The ‘Glasgow syndicate,’ the Cassel Gold Extraction Company, the New Zealand Crown Mines Company, Thomas Melville and Peter Ferguson’s New Era Syndicate were therefore all connected in a serious of business associations, which all had strong Glasgow connections. The 1889 wooden cyanide tank at Ferguson’s New Era Works (site T13/104) survives as the earliest monument this Glaswegian influence.

The archaeological record therefore supports the premise that international capital played a major role in the New Zealand goldfields, particularly in the 1890s-1900s. Several of the large and well-equipped batteries that survive today were paid for by overseas capital. A ‘trickle-down’ effect then appears to have occurred, with locally-financed companies using the imported new technologies (especially the cyanide process), and second-hand parts entered the local market when the large batteries shut down; Cherry’s Battery at Karangahake and the Robert brothers’ battery at Thames were both 5 stamp mills that used very heavy stamping equipment sourced from closed large local batteries.

Applying Theoretical Models of Technological Development

The combination of a macro/micro-innovation analysis of stamp mill technology and the identification of various influences and agents at play in the New Zealand goldfields confirms
that the situation was complex; as Joel Mokyr (1990: 242) has pointed out “technological change and the creation of new information are processes that do not obey the laws of arithmetic.” The technology was overwhelmingly international in origin (mostly from the ‘core’ areas of Australia, Britain and America) but the actual equipment was made both overseas and in New Zealand, overseas and local agency can be identified in the selection and use of this machinery, and there was a change over time that was generally evolutionary, but had many irregularities as old machinery continued in use.

The next step is to consider this information within a global/national/local conceptual framework, to consider how the various elements interacted, and to describe how New Zealand took its place within the international mining industry. This is done in terms of the ‘core-periphery’ model suited to the discussion of technological dependence and technological sovereignty. There is a particular focus on identifying local agency, which is critical to determining whether New Zealand simply followed the rest of the world or had a hand in determining its own technological development.

The first stamp mills in New Zealand were certainly dependent on imported knowledge and/or machinery. The very earliest mills were probably made from locally available materials along ‘Cornish’ lines (see Figure 18 in Chapter 3), using knowledge that had been brought to New Zealand by immigrant miners. The first ‘engineered’ mills were imported from Australia, from A.K. Smith’s Carlton Foundry or Langland’s Foundry, both in Melbourne. Unsurprisingly early New Zealand manufactured equipment was probably based largely on Melbourne-manufactured plant, and some early New Zealand mills such as the Young Australian (1871, Kincaid & McQueen, Dunedin) bear many similarities with the Langland’s Foundry batteries, even in cases where different frame forms give them quite different superficial appearances. The early mills used basic collar or screw-mount tappets, which were only suitable for relatively lightweight stamps, and had simple rectangular shaped mortar boxes with vertical clamp- or bolt-on screen frames. The potentially very early Auckland-made Printz’s Battery (late 1860s or early 1870s) has an unusual mortar box form (with the anachronistic use of timber) but otherwise exhibits conventional technology for the period. The identification of the ‘Australasian type’ of iron-framed stamp mill (made in both Australia and New Zealand) is of note, as it confirms the on-going interaction between Australian and New Zealand manufacturers. However, as already discussed, this type of mill generally showed resolutely conventional technology. The archaeological evidence is therefore that Australia provided an initial ‘base-load’ of conventional technology, but there is little subsequent archaeological evidence for the supply of advanced or innovative technology. New designs that did come across the Tasman had their origins elsewhere; for example, the 1889 Bonanza Huntington Mill was manufactured in Sydney, but the foundry was owned and operated by Parke & Lacy, a San Francisco-based company.

After the initial ‘seeding’ technology, the sources of technological improvements appear to shift from Australia to America and Britain, and the complexities in interpreting the uptake of this new technology increase. The importation of American-manufactured machinery and designs from the 1880s to the 1900s is of some interest, and raises some questions that can not all be answered here. Many American designs such as the gib tappet, Wilfley table and Pelton wheel were widely adopted in New Zealand, and have left ample archaeological evidence. However, although a number of American-manufactured stamp mills were imported, with the exception of the Allis-Chalmers (Milwaukee) Golden Blocks mill none of these machines bears much relation to the ‘normal’ or ‘standard’ New Zealand 5 stamp mill. While they use features that were adopted in New Zealand (such as the gib tappet and inclined
slotted screen mount), the use of multiple discharge boxes was not seen in other local mills after the 1870s, and the use of 4 post frames (in iron or wood) was limited to these American machines. While it is not in the scope of this thesis to attempt an archaeological comparison with American battery sites, perusal of work such as White (2010), Hardesty (2010) and Morley & Foley (1965) clearly show that more ‘conventional’ stamp mill forms (5 stamp single outlet mortars, battery post timber frames) were widely used in the USA. Why these mills do not appear in the New Zealand archaeological record is not known, although it does appear that that when machinery from Anglo-American companies was imported, there was a preference for British-made machinery, such as the Taitapu Battery manufactured by Fraser & Chalmers in England and the Brush dynamos at Bullendale.

The role of the British syndicates from the 1880s onwards was considerable, with some of the largest and most complex mills built using London money. This process could be expected to promote the direct importation of international technology, and reduce the effect of local agency as more decisions were made from the head office. The direct importation of technology in the form of the complete ‘international’ mill can be seen in some of the largest remaining machinery; the British-made Homeward Bound (1899) and Taitapu (1897) batteries are the best surviving examples of this process. However, even these mills show some consideration of local factors; both were powered by Pelton wheels that were ideal for New Zealand’s conditions, and Berdans were used at both sites, despite these being unusual in Europe (and, notably, Pelton wheels and Berdans were both American developments). In addition, the Homeward Bound was modified slightly when it was moved from Waipori to Macetown, with the addition of concrete mortar foundations and a Wilfley table. Clearly some form of local agency was operating with regard to the selection of equipment, even in these most extreme examples of direct technological importation, and agency was certainly present in the form of the local promoters such as Ziman (Reefton) and Farrell (Macetown) who travelled to Britain to raise capital.

In the same period the small and mid-size stamp mills also showed an evolution in technical detail, although this is obscured somewhat in the archaeological record by the survival of many older machines, some of which were recycled numerous times. Their development is seen in the use of imported machinery and designs such as the gib tappet, inclined slot mortar box mount, Pelton wheel, Wilfley table, cyanide process and electric power, together with a general increase in stamp weight over time. The key question in this process is to what degree was the adoption of these changes simply the result of international influences, or to local agency. The presence of these features in mills that were erected by locally-financed companies is a strong indication of local agency, and this is reinforced considerably in cases where the machinery was purchased new because decisions made in the purchase of second-hand machinery were often based on availability rather than suitability. The original Nugget Battery was built in 1870 using second-hand (manufactured in 1865) Australian-made machinery, but the 1903 rebuild by the Shotover Quartz Mining Company used new plant manufactured by Kincaid & McQueen in Dunedin that while not exceptional, was comfortably contemporary in its design. It indicates that international designs had been adopted by local manufacturers, and were being selected by local mining companies.

The role of local manufacturers is significant and informative; in particular their roles as followers or leaders in the adoption of new technology. The role of A.&G. Price of Thames is particularly important in this context. This company was an early adopter and manufacturer of a number of significant designs in the goldfields, most notably the Pelton Wheel (licenced in 1884, 4 years after the American patent was taken out) which rapidly came to dominate the
supply of water power to many industries, not just gold mining. The Price Brothers also were the most common local manufacturer of the improved inclined-slot mortar box, and the only identified local manufacturer of the Blanton cam. Far from being technologically dependent, the archaeological record indicates that A.&G. Price were quick to take up new and improved designs and manufacture and promote them. As Orser (2009b: 255) has pointed out, “a periphery of a core may function as a core to another periphery,” and A.&G. Price appears to have taken on this role.

A.&G. Price also had a role in one of the most significant technological developments in the goldfields, the installation of the hydro-electric plant at Bullendale in 1885/1886, as they supplied the two Pelton wheels that provided the primary power source. Bullendale is of considerable significance in this discussion, not because it was the first such plant in New Zealand, but because it was the result of the local mine manager, Fred Evans, and the mine owner, George Bullen, seeking out a better way of powering the Achilles Battery. The construction of the power plant was the result of local agency attempting to address a problem created by local environmental conditions (the lack of water supply for the battery turbine). The end result was extremely ‘international’; two New Zealand-manufactured American-designed Pelton wheels drove two American-designed British-manufactured dynamos, which in turn powered a British-made motor that was based on a German dynamo design. Other individuals involved with the project were the electrical contractors, Walter Prince and Edward Fletcher, both of whom had trained in Britain and worked in Australia.

Another critical element to this discussion is whether there was any local innovation in New Zealand, or whether international designs were simply adopted here. The development and widespread use of the B.&M. Agitator (with surviving examples at the Union Battery in Waihi and Snowy River Battery) indicates that local innovation did occur. There were numerous New Zealand patents related to goldfields machinery, of which Ashcroft’s Crusher at Terawhiti is a rare (possibly unique) example of a machine that was both made and has survived, albeit both derivative (based on the Berdan design) and unsuccessful (only two were ever made). But the ultimate example of New Zealand innovation in the goldfields lies outside the realm of hard rock mining, and in the development of river and paddock dredge technology, in which Otago was a world leader (Hearn & Hargreaves 1985).

A related subject that must also be considered is local pragmatism, which often operated at the most local and minimally funded level. Limbaugh (1998) has discussed pragmatism in the American gold fields, but his focus was more on pragmatic design at the regional level, while what is of interest here is pragmatic adaptation at the very local level. The reuse and modification of old and abandoned equipment, or what would appear to be the uneconomic repair of worn out machinery, are all evidence of local pragmatism, and therefore also of local agency. The repairs to the Young Australian Battery indicate that money was far more important than time to the last operators, as it would have been much quicker to replace the worn parts than repair them. Similarly, the Depression-era mining of the 1930s was often carried out at a bare minimum level of funding, and a good example of pragmatism in this situation is the installation of flat paddles on the No. 2 South Larry’s Battery Pelton wheel after the original cups had gone missing; a local blacksmith could easily make the sheet metal paddles while a set of new cups would need to be purchased from a foundry.

Away from direct considerations of mining machinery, the 1880s also saw the development of the New Zealand School of Mines movement. While the output of fully-qualified graduates was never large, the enthusiasm of the mining population to gain education in mining shows
that the local (local, regional and national) mining communities were not simply actors, but wished to participate more knowingly in the mining system. Staff at the schools were generally closely associated with the mining industry; for example D.B. Waters was the mine manager for the Shotover Quartz Mining Company in 1898, and would later teach at the Otago School of Mines (AJHR 1899 C3: 96). The surviving libraries and course notes at the Thames, Reefton, Coromandel and Otago Schools can be seen as archaeological evidence (the books and papers are, after all, physical artefacts) of the technological information that the Schools helped to disseminate.

It is therefore possible to demonstrate local agency in the New Zealand goldfields, with local communities valuing and seeking technological information, local companies manufacturing machinery, and local mining companies making deliberate decisions about the use of machinery. The influence of the large British syndicates in undeniable, and while some towns such as Reefton, Waihi and Waiuta were largely (or entirely in the latter case) company towns, there was also a large gold mining community that was locally funded and made decisions based on local imperatives. Burt’s comment quoted at the beginning of this chapter that mining sites from around the world are all very similar does have a certain truth, but the very detailed examination of the New Zealand goldfields shows that the technology was the result of the complex interaction of many agents acting locally, nationally and globally; more akin to a network with areas of particular innovation and influence, than a simple core-and periphery model.

Towards a New Model: New Zealand Technological Participation

In applying the criteria of the Technological Dependency and the Technological Sovereignty models it is clear that although the stamp mill technology used in New Zealand was overwhelmingly international in nature, with an initial importation from Australia, and an ongoing importation from Britain and America, much of the selection of this technology was due to local agency. Even the largest British-financed mills involved local experts and promoters. Todd (2009: 236) identified the critical issue for identifying technological sovereignty as being whether new technology was freely and independently sought out, as opposed to technological dependency where choice was eliminated by political, economic or ideological/cultural controls. The archaeological evidence in New Zealand very clearly favours the former; that of technological sovereignty.

However, I would suggest a slightly different model actually fits the evidence better: New Zealand Technological Participation. This sees New Zealand as an active participant in the development and use of gold mining technology: it acknowledges that most technological development occurred overseas (where the mining and manufacturing industries were larger and better financed), but identifies active choice together with some on-going development and innovation here (such as the B&M Agitator tanks). The New Zealand mining industry’s record as an early adopter of technology (notably cyanide treatment and hydroelectric power) support this concept of active participation, as does the role of A.&G. Price in rapidly commencing local production of overseas innovations (the Pelton wheel and Blanton cam). It has always been tempting for authors to claim some degree of invention or innovation for their own country (eg, Davey 1998, 1996; Menghetti 2005), and Limbaugh (1998: 28) has specifically commented on this in the American context; “the notion that Yankees were more ingenious than people from other lands is an ethnocentric stereotype born out of the excessive nationalism of the nineteenth century.” The concept of participation avoids any notions of
nationalism, while still acknowledging that each of the ‘gold mining’ countries had an input into the on-going development of mining and milling technology. New Zealand was a small player in this international context, but was an active participant.
Chapter 11
Putting the Man in the Machine

The previous chapters have all dealt with the technological and engineering aspects of the stamp mill. This has addressed a number of issues, such as ideas of technology transfer, adaptation and innovation, but has left only partially answered one important aspect of true archaeology; the role of people. Managers, engineers and financiers were all responsible for decisions regarding battery design and management, but the role and experience of the workers, who were always in the majority, has yet to be examined.

Gold mining operations employed men in a number of different roles, including underground miners, engine drivers (who operated the winding engines) and millmen. Within the mill were a variety of different jobs, including feeders, amalgamators, furnace men, cyanide plant men, and the manager (Stephens n.d.). The number of men that worked in a mill varied depending on the size of the mill, the processes used, and the degree of automation employed. Smaller mills often had four to five workers, examples being the 10 stamp Gallant Tipperary Battery (ex-Nugget) which had four men and a battery manager to work the mill 12 hours a day (AJHR 1889 C2: 58), and the 10 stamp Big River Battery that was usually manned by two feeders, an amalgamator and the battery manager, and ran for two 8 hour shifts per day for six days a week (Wright 2004: 73). At the other end of the spectrum the 200 stamp Victoria Battery at Waikino employed nearly 200 workers in a wide variety of roles (McAra 1988: 230-235, 271).

To return to the statement that Raistrick made in 1973 (p.12) that “the recording of a factory is as much a recording of the place in which lives have been spent as one which sheltered archaic machines,” the intention here is to examine the stamp mill as a place of work, and examine the archaeological evidence for the working lives of the men (based on historical sources, it was always men) involved in running the machines. This study has two main elements: the work undertaken, and the working environment. Two recent pieces of archaeological research are relevant to this discussion. Geraldine Mate (2010) has examined social meanings in an historic industrial landscape, that of Mount Shamrock in Queensland, Australia, which included an examination of the ‘sensory landscape’ (Mate 2010: 289-291). This is the way that people experience their environment, including their place of work, in terms of their senses of sight, touch, hearing and smell. The other relevant research is Paul White’s (2010) examination of the Skiddo Mill in California that considers the archaeological evidence for decisions made regarding the on-going repair and maintenance of an ageing mill.

The approach taken here is to examine the archaeological evidence for actually building, running, maintaining, repairing and modifying stamp mills, using historical sources and photographs to provide additional information and context. In the same way that a detailed examination of machine design was used to assess technological adoption and adaption, detailed examination of the evidence of wear, repair and pragmatic modification (in effect, a usewear analysis) is used to assess workplace decisions and actions. It is this evidence of human agency that places people back into the battery context in an everyday way. The detailed volumetric and weight calculations of stamps used in Chapters 8 and 10 to consider design parameters of mills are used here to consider the weights that workmen had to contend with in their everyday activities. Personal reminiscences and first hand accounts, such as those by Stephens (n.d., 1986) and McAra (1988) are used to add to the account.
Modern observations are also employed in this chapter. Recent Department of Conservation restorations of several stamp mills in the South Island used many of the same techniques for working on the machinery as when the mills were first built, and can almost be considered exercises in experimental archaeology. In addition, a number of stamp mills have been re-erected for public display and are regularly operated. The opportunity was taken to record the noise levels of some of these to attempt to quantify the experiences of the millmen that worked in the batteries.

This chapter considers these themes in three main sections:

- Archaeological evidence for construction, repairs, maintenance and modification.
- Quantifying the effort required.
- The working environment & the sensory experience.

**Archaeological Evidence of Construction**

The decision to build a battery, where to build it, and what machinery to use, can all be regarded as ‘management’ decisions. In a small syndicate or partnership the decision makers and workers may have been the same people, but in large mining companies they were certainly not. But whatever the process undertaken, each decision would lead to physical work on the ground to build, run, maintain and repair the battery. Every existing stamp mill had to be constructed by hand, often in very remote places and in poor weather, at a time before modern transport, portable lifting equipment and power tools were available.

Construction of a mill involved site preparation, transport of all of the framing and machinery and then assembly of the battery and battery house. Many of these jobs would be let as contracts rather than carried out by the mining company’s employees. As the preferred location for a mill was on a hillside (to make use of gravity flow of ore through the milling process) site preparation often consisted of cutting terraces and the construction of retaining walls and building platforms. As an example, measurement of the rock cutting at the OPQ battery site at Waipori (Figure 348, site H44/26) indicates that approximately 63,000 cubic feet (1,800 cubic metres) of rock had to be broken and removed to prepare the site (not including excavation for foundations). This was done in 1899, when dynamite and gelignite were both available to break the rock, but all of the physical removal would have been done by men and wheelbarrows.

*Figure 348. The site of the 1899 OPQ Battery at Waipori.*
Transport of the machinery was then required, and in remote places this could be extremely difficult. River transport, horses and oxen were used wherever possible, but sometimes the last legs of a journey would be carried out using manpower. The boiler for the Ajax battery (site L30/31, Figure 349) weighs 4 tons and took 170 men six weeks to haul up the side of the mountain range from Reefton to the battery site (Bolitho 1999: 25; Latham 1984: 99; Salmon 1963: 166). In some cases mine roads were built to provide access, with large cuttings and embankments (Figure 350).

**Figure 349. The boiler at the Ajax Battery (site L30/31) in 2011.**

The Alpine (site F42/265) and Albion (site Q27/112) batteries have both been disassembled to be moved, but were eventually abandoned on site prior to removal, while the Waimea battery (site M28/5, Figure 351) is a complete set of machinery that was abandoned in transit.

**Figure 350. Jitlada Innanchai standing on a bench cutting on the road to the Britannia Mine (site L29/15).**

**Figure 351. Abandoned parts from the Waimea Battery (site M28/5).**

Once at the site, the battery would need to be erected, which was a skilled task as all of the bearings and working parts had to be correctly aligned, and some contemporary engineering texts (eg. Louis 1902) contained detailed instructions. Skilled millwrights or engineers were often employed to oversee this work, such as a Mr. Reid who was engaged to erect the Young Australian mill in 1874 (Ulrich 1875: 83). Heavy lifting was done by block and tackle or by jacks. Frame timbers and other elements were often marked to assist reassembly, usually with of matching sets of Roman numerals at joints (Figures 352 and 353).
Figure 352. Re-assembly marks carved into the frame of the Homeward Bound Battery (site F41/477). Movement of the frame due to decay has opened up the joints.

Figure 353. Roman numeral carved into a cross-sill at the Alpine Battery (site F42/265).

Once the machinery had been erected, the working clearances such as stamp drop needed to be set before crushing could commence. Again, detailed instructions were available:

In setting up a stamp, the head is first placed in position upon a piece of 3-inch plank laid upon the dies, which latter are supposed to be already in their places. The stems are then dropped in and tightened by a few blows from a heavy sledge hammer on their upper ends, a piece of board being interposed to keep the top of the stem from being battered. Unless the stem-sockets are much worn, it is best to drive the stem directly into the head. When the fit is a bad one, a piece of canvas or of thin sheet iron cut to fit the socket exactly may be wrapped around the end of the stem, but it is far better to dispense with anything of the kind. If the stem is then hoisted up, and the shoe, with its wedges tied on, placed on the plank, the
stem and head together being then dropped over it; by dropping the whole several times on the plank, the shoe is driven home. As soon as the wedges are thoroughly wetted by the battery water, they expand, and hold the shoe very firmly in its place.

The plank is then taken out, and a block equal to the desired length of drop is set on each die. The tappet is then slipped over the stem with its gib in place and allowed to slide down until it touches the point of the cam, the latter being in its highest position. The tappet keys are then driven well home, and the stamp is allowed to drop gently a few times till every part has been forced into its place. (Louis 1902: 183-184)

As this passage makes clear, every stage of the process involved manual labour. The stamps, which could weigh up to 1250lb in New Zealand, were lifted using a block and tackle (or chain block) (Stephens n.d.), and a sledgehammer (often with the use of a wedge) was used for mounting and dismounting various parts such as stamp heads.

Archaeological Evidence of Repairs & Maintenance

Once the stamp mill was in operation, on-going maintenance, adjustment and repairs were necessary. Stamper batteries and other processing equipment were designed and built to be hardy, as they were exposed to constant pounding and shaking, while the ore and mill pulp were highly abrasive, and almost every part of a mill wore or was subject to breakage. As discussed in Chapter 5 many parts were designed with this in mind, and over time some design features (such as Blanton cams) were developed to make repairs easier and quicker, while other parts (such as the gib tappet) overcame design weaknesses. Contemporary accounts such as Louis (1902) and Del Mar (1912) make many references to wear and replacement of parts (especially shoes, dies and screens), and Del Mar (1912: 31) commented that larger mills had repair crews, who were specifically employed to carry out repairs and maintenance, while smaller mills only had the millman. At the Snowy River Battery (site L31/37), Stan Stephens recounted how it was the job of the amalgamator to look after the two mortar boxes allotted to him, and to replace any shoes, dies, liners or false bottoms that had become worn (Figure 354) (Stephens n.d.).

Figure 354. Worn out and discarded dies and shoes at the Snowy River Battery (site L31/37).
There is ample evidence of wear and breakage in the archaeological record, often (but not always) accompanied by evidence of repair and maintenance. For example, the design weakness of the screw tappet has been discussed in Chapters 5 and 8, and there is evidence for running repairs to these tappets by shimiming the damaged thread (Figure 355).

**Figure 355. A screw tappet on Anderson’s Battery (site F41/473) with a badly worn thread.**

Tappets were light and easy to repair, but replacing worn or damaged cams involved a much greater degree of effort, as the camshaft would need to be lifted out of the machine and enough cams removed to reach the damaged item. As discussed in Chapter 5 above, the introduction of the Blanton cam cut the task of removing cams on a 10 cam camshaft from a day to less than half an hour in one case (Richards 1906: 194). From the archaeological record it is not possible to tell exactly how long a set of cams remained in service, or how much work they did, but cams in every condition from almost pristine to completely worn out were observed (Figures 356 and 357).

**Figure 356. Almost unworn cams on the All Nations Battery (site F41/483) in Otago.**

**Figure 357. A worn cam face on the Johnston’s United Battery (site M25/73) in Nelson. The face has begun to break up, and once the cam was in this condition the rate of wear would have increased rapidly.**
There is also archaeological evidence on the goldfields of parts being repaired and kept in service long after they should have been replaced. The Young Australian Battery (site F42/25) has already been discussed in Chapter 10 as an example of a very worn mill, and its cams and tappets have all been repaired despite being items that were designed to be renewable (Figure 358). The time and effort implications of this are considered further below.

**Figure 358. Repaired cams and tappet on the Young Australian Battery (site F42/25).**
*Iron strips have been riveted to the worn face of the cams and iron rings have been shrunk on the tappets.*

There is evidence of a hierarchy of replaceable parts: shoes, dies, screens and liners would be regularly replaced; cams and tappets would require occasional replacement; other parts would require replacement only rarely. Mortar boxes, even when equipped with liners, could wear out, and the remains of the Big River Battery (site L31/4) illustrate this. The existing boxes were ordered in 1914 to replace the worn out originals (Wright 2004: 73), and the replacement boxes have themselves worn through in places (Figure 359). To move a mortar box, which weighed several tons, required the use of strong tackle or heavy jacks after having first lifted and removed all of the stamps (Louis 1902: 123-127).

**Figure 359. A hole (centre of photo) worn right through the side of the ore feed in one Big River Battery mortar box.**

As well as wear, breakage was a problem. Cast iron is strong but brittle, and once broken it was not generally possible to make a welded repair; instead repairs were usually effected by riveting or bolting a sheet iron patch over the break. The Victory water wheel at Waipori (site H44/61) has iron straps bolted on over a fractured section of cast iron shroud (Figure 360), which would have required the use of a forge to cut and shape the iron sheet.
Archaeological Evidence of Modification & Improvisation

Modifications to stamp mill machinery were also often required. As discussed in Chapter 5 battery operation depended on a number of parameters such as stamp drop rates and heights and mortar box outlets, and it was often thought necessary to alter these. Some of these parameters were within the adjustment limits of the machines, but others required changes to the machinery. For example, stamp drop height could be altered by adjusting the tappet height, but stamp drop rate depended on either adjusting the speed of the power source or the gearing of the camshaft. If the latter was required different sized pulleys or drive gears would be required. In an ideal world the replacement parts for either repair or modification would be a perfect fit, and archaeological observation would probably not be able to identify them. However, the reality of mill operation was often that spare parts were not readily available, or the decision was made not to purchase them, and instead on-site repairs or modifications were carried out using parts and materials to hand, and these changes are often identifiable in the archaeological record.

Figure 361. A detail of the geared drive wheel at No. 2 South Larry’s Battery. The remains of the timber packing can be seen bottom left, hanging from the gear wheel.

The No. 2 South Larry’s Battery (site L30/7) near Reefton, has evidence of several modifications to its operation; the main drive gear on the camshaft has had timber packing added around its circumference, both increasing the effective diameter of the wheel and converting it from geared drive to flat-belt drive (Figure 361); the battery post on the opposite end of the battery has scoring from a gear wheel that is no longer present; and the Pelton Wheel has been rebuilt using flat vanes after the original curved buckets were removed (Figure 362).
Figure 362. The turbine wheel at the No. 2 South Larry’s Battery.

The Come-in-Time Battery (site G41/251) at Bendigo was constructed in 1908 from half of the nearby Maltilda Battery, and its timber frame shows evidence of changes to the mill design. In particular it has gouges on one of its cam beams from a different camshaft pulley than the one presently in place (Figure 363).

Figure 363. The Come in Time battery in 1993.

A step further down the technological ladder from modified stamp mills were the improvised stamp mills that were constructed from various second-hand parts. Examples of this type of mill include Currie’s Battery (E40/24) that was built in the 1940s using a mixture of parts, including a drive pulley from the nearby Bullendale hydro-electric plant (Figure 364) (site E40/28), and ‘Tiger’ Beale’s small single stamp battery (site E41/82) that he built beside Pleasant Creek in the 1930s (Figure 365). These mills were built by small groups (probably by an individual in the case of Beale) with minimal capital, and evidence of improvisation can be seen in the mixture (and often mismatch) of parts.
The only tools available for construction, maintenance and repairs on most battery sites were basic hand tools, the forge and the block and tackle or chain block. The use of the block and tackle/chain block in both historic and modern restoration contexts is shown in Figures 366 and 368. As the image of the OPQ battery (later moved to become the Homeward Bound) being erected in 1899 shows (Figure 366), the structure was built using manual labour alone. Although only a 10 stamp mill, the size and construction of the OPQ/Homeward Bound frame
was of a similar scale to many of the largest mills in the country (which simply repeated the same structural elements), so it can be seen how even a large battery could be built using simple manual labour (Figure 367).

Figure 366. The Otago Pioneer Quartz (OPQ) battery under construction at Waipori in 1899. In this view the top guide beam is being lifted into place by four men using a block and tackle at each end. (Peter Chandler Papers, Hocken Library).

Figure 367. The second 50 stamps being constructed at the Victoria Battery in 1898. The only lifting equipment in view is two ladders (NZMR Vol. 1 No. 12, 1898).
Figure 368. Using a lifting frame and chain block during the restoration of Kirwan’s Reward Battery (site L30/62) by the Department of Conservation in 2010 (J. Staton, DoC, Greymouth).

The hand tools used in the stamp mills were also often simple. Historic photographs show such items as spanners, shovels, hand planes, hammers, saws and wheelbarrows (Figure 369). Once again, during the recent restoration of several stamp mills, while using power tools for cutting timber, Department of Conservation staff also used many of the same tools as the original builders, such as large spanners and sledgehammers (Figure 370).

Figure 369. The interior of Johnston’s United Battery (site M25/73). Two men hold shovels for clearing pulp from the tables, one man has a pan for washing up and one man has a large spanner for working on the machinery (Department of Conservation, Nelson).
Some larger batteries had well-equipped workshops, the ultimate example being the Victoria Battery at Waikino that in addition to a full engineering workshop had a foundry where large castings such as mortar boxes were made (Figure 371) (McAra 1988: 140, 233-4). However, most smaller batteries would have only had a small workshop equipped with a permanent or portable forge, an anvil and some basic tools (Figures 372 and 373).
Figure 372. A portable forge at Printz’s Battery (site D46/150).

Figure 373. Kevin Jones demonstrating the use of a forge on a New Zealand Archaeological Association fieldtrip.

Quantifying the Effort Required

The above archaeological evidence of repairs and maintenance shows some of the tasks that workers had to carry out, and by using a similar detailed engineering approach to that used in Chapter 8 it is possible to begin to quantify the efforts of these workers. The calculated stamp weights given in Chapter 8 were based on volumetric calculations of the stamp assemblies using field measurements taken during the archaeological survey, and this approach can be used on other items of the mill machinery. Once these weights are known, the work (unit = foot-pound) involved in lifting these items in and out of the machines can be calculated. The required work can then be compared to contemporary measurements of the capabilities of working men.

Estimates of energy or power required for various tasks were popular in the 1970s and 1980 in New Zealand archaeology (eg Fankhauser 1986; Law 1970; Mangan & Nichol 1981), but
have not been fashionable more recently. The sources of error and potential subjectivity in estimating the energy required for digging with a digging stick or collecting ti roots on a hillside are possible reasons for this. However, when considering mechanical engineering, it is possible to make reasonably exact calculations regarding the weight and mass of different parts of a machine, and also the assistance to be gained from the known methods of handling heavy weights, particularly the block and tackle.

The use of the block and tackle provides a mechanical advantage, the extent of this advantage depending on how many returns the rope or chain makes (Figure 374). At each extra return the pull required to lift a given weight is reduced, while the distance the weight is lifted decreases and the length of chain to be pulled through the block increases (Table 51). An added advantage of using a block and tackle is safety, as the weight being lifted can be easily held stationary by securing the lines.

![Figure 374. Block and tackle arrangements for 1 to 5 part lines (Oberg & Jones 1917).](image)

Table 51. The mechanical advantage of the block & tackle (Oberg & Jones 1917).

<table>
<thead>
<tr>
<th>Number of Rope Lengths Shortened</th>
<th>Ratio of Load to Pull</th>
<th>Efficiency, Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manila Rope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.91</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>2.64</td>
<td>88</td>
</tr>
<tr>
<td>4</td>
<td>3.30</td>
<td>83</td>
</tr>
<tr>
<td>5</td>
<td>3.84</td>
<td>77</td>
</tr>
<tr>
<td>6</td>
<td>4.33</td>
<td>72</td>
</tr>
<tr>
<td>7</td>
<td>4.72</td>
<td>67</td>
</tr>
<tr>
<td>8</td>
<td>5.08</td>
<td>64</td>
</tr>
<tr>
<td>9</td>
<td>5.37</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Wire Rope                        |                      |                      |
| 2                                | 2.73                 | 91                   |
| 3                                | 3.47                 | 87                   |
| 4                                | 4.11                 | 82                   |
| 5                                | 4.70                 | 78                   |
| 6                                | 5.20                 | 74                   |
| 7                                | 5.68                 | 71                   |
| 8                                | 6.08                 | 68                   |
| 9                                | 6.46                 | 65                   |
| 10                               | 7.08                 | 59                   |
To take the example of the OPQ/Homeward Bound battery (site F41/477), the survival of both the 1899 photograph showing it being built (Figures 366 & 375) and the structure itself (Figure 376) allows the mechanics of its construction to be investigated. Figure 375 below shows how the upper guide beam was lifted into place by four men using chains running in two block sets, with two men at each end of the beam. Close inspection of the image shows that the stamp guides were in place, bolted to the rear of the beam. All of these structural elements survive at the Homeward Bound site, and can therefore be measured (Table 52), and the volume and weight of the timbers calculated.

Figure 375. Detail from the photograph of the OPQ Battery under construction. Showing the upper guide beam being hoisted into position by four men using two chain blocks (Peter Chandler Papers, Hocken Library).

Figure 376. The Homeward Bound Battery in 2011. The upper guide beam seen in the 1899 OPQ view is in place.
Table 52. Dimensions of Homeward Bound guide beam and stamp guides.

<table>
<thead>
<tr>
<th>Element</th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guide Beam</td>
<td>13 feet 7 inches</td>
<td>14 ½ inches</td>
<td>11 ½ inches</td>
</tr>
<tr>
<td>Stamp guide half (4 reqd.)</td>
<td>5 feet</td>
<td>14 ½ inches</td>
<td>3 7/8 inches</td>
</tr>
</tbody>
</table>

Based on these measurements the total volume of timber in the beam and guides is 39,270 cubic inches, or 22.73 cubic feet. The battery timbers are made from North American Douglas Fir (Richardson 2012), also known as ‘Oregon Pine,’ that has a seasoned and dry mass of 530 kg/cu.m (www.simetric.co.uk/si_wood.htm) or 33.09 lb/cu.ft. The calculated weight of the timber in the combined beam and guides is therefore 752 lb. In addition the beam contained 16 long bolts when it was being lifted into position, and the calculated weight of each bolt assembly is 6.4 lb, making a total of 102.4 lb extra weight. The total calculated weight of the entire assembly is therefore approximately **854 lb (387 kg)**. The work required to lift the beam assembly can also be calculated. The upper beam is 17 feet 3 inches above the level of the cross sills of the battery, meaning that the 854 lb beam had to be lifted 17 feet 3 inches, requiring **14,732 ft-lb** of work.

A weight of 854 lb is clearly too heavy for even four men to easily handle directly (nearly 215 lb or 100 kg each), particularly for a vertical lift three times the height of a man. The mechanical advantage of the block and tackle now needs to be considered. The 1899 photograph appears to show that a duplex chain arrangement was used at each end of the beam, which should give an effective advantage ratio of 2. Each block and tackle had to lift 427 lb, which meant that a pull of 214 lb was required, or 107 lb (48 kg) per man. If three returns were used (the quality of the historic image is not perfect, and this remains a possibility), then the pull per man reduces to 71 lb (32 kg) (plus a small amount for friction). If the calculated 14,732 ft-lb of work required to lift the OPQ/Homeward Bound guide beam is split between the four men involved, each had to perform 3,683 ft-lb of work, and comparison with contemporary figures (Tables 53 & 54) suggests that this was well within the capabilities of contemporary workmen.

Table 53. The power of men working at a crane (Clark 1897). These results were arrived at experimentally, with various workmen timed in their efforts to lift set weights using a geared crane.

<table>
<thead>
<tr>
<th>No. of Experiments</th>
<th>Statical Resistance of the Load at the Handle</th>
<th>Load Raised</th>
<th>Time in Raising</th>
<th>Equivalent Power in Foot-pounds per Minute</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>1050</td>
<td>1.5</td>
<td>11,550</td>
<td>Easily done by a stout Englishman.</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>1575</td>
<td>2.25</td>
<td>11,505</td>
<td>Tolerably easily by the same man.</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>2100</td>
<td>2.0</td>
<td>17,525</td>
<td>Not easily by a sturdy Irishman.</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>2625</td>
<td>2.5</td>
<td>17,529</td>
<td>With difficulty by a stout Englishman.</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>3125</td>
<td>2.5</td>
<td>20,990</td>
<td>Do. by a London man.</td>
</tr>
<tr>
<td>6</td>
<td>35</td>
<td>3675</td>
<td>2.2</td>
<td>27,562</td>
<td>With utmost difficulty by a tall Irishman.</td>
</tr>
<tr>
<td>7</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>2.5</td>
<td>24,555</td>
<td>Do. by a London man.</td>
</tr>
<tr>
<td>8</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>2.83</td>
<td>21,427</td>
<td>With extreme labour by a tall Irishman.</td>
</tr>
<tr>
<td>9</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>3.0</td>
<td>20,312</td>
<td>With very great exertion by a sturdy Irishman.</td>
</tr>
<tr>
<td>10</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>4.05</td>
<td>15,134</td>
<td>With the utmost exertion by a Welshman.</td>
</tr>
<tr>
<td>11</td>
<td>&quot; &quot;</td>
<td>&quot; &quot;</td>
<td>-</td>
<td>-</td>
<td>Given up at this time by an Irishman.</td>
</tr>
</tbody>
</table>
Table 54. Muscular Power of a Man and of Various Animals (Forbes 1965).

<table>
<thead>
<tr>
<th></th>
<th>Pressure Exerted (lbs)</th>
<th>Velocity (feet per second)</th>
<th>Foot-pounds per second</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. draft horse</td>
<td>120</td>
<td>3.6</td>
<td>432</td>
<td>1.00</td>
</tr>
<tr>
<td>Ox</td>
<td>120</td>
<td>2.4</td>
<td>288</td>
<td>0.66</td>
</tr>
<tr>
<td>Mule</td>
<td>60</td>
<td>3.6</td>
<td>216</td>
<td>0.50</td>
</tr>
<tr>
<td>Donkey</td>
<td>30</td>
<td>3.6</td>
<td>108</td>
<td>0.25</td>
</tr>
<tr>
<td>Man, pumping</td>
<td>13.2</td>
<td>2.5</td>
<td>33</td>
<td>0.076</td>
</tr>
<tr>
<td>Man. Turning winch</td>
<td>18</td>
<td>2.5</td>
<td>45</td>
<td>0.104</td>
</tr>
</tbody>
</table>

Having applied this type of engineering analysis to the OPQ/Homeward Bound Battery, where at least some of the construction methods are known, a similar approach can be used for other sites. In particular, the Young Australian Battery (site F42/25) has already been identified as a machine that has been repaired to an extreme extent. The cams and tappets have been extensively repaired when it would have made much better engineering sense to replace these items. The decision was obviously made to undertake this work, presumably at a considerable cost in time but saving in money. A reasonable question is therefore: what work was involved?

The weights of various components of the Young Australian Battery can be calculated from their dimensions (Table 55), using the same constant for the weight of iron (0.278 lbs per cubic inch) as used in Chapter 8.

Table 55. Summary of volumes and weights of camshaft and cams at the Young Australian Battery.

<table>
<thead>
<tr>
<th>Element</th>
<th>Length</th>
<th>Diameter</th>
<th>Volume</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camshaft</td>
<td>14 ft 7 in</td>
<td>3.875 in</td>
<td>2063.78 cu. in.</td>
<td>573 lb</td>
</tr>
<tr>
<td>Cam (each)</td>
<td></td>
<td></td>
<td>216 cu. in.</td>
<td>60 lb</td>
</tr>
<tr>
<td>Camshaft assembly</td>
<td></td>
<td></td>
<td></td>
<td>874 lb</td>
</tr>
</tbody>
</table>

Figure 377. The Young Australian Battery camshaft (573 lb), cams (60 lb each) and stamps (565 lb).
The total camshaft assembly (Figure 377) therefore weighs 874 lb (397 kg), excluding the drive wheels on either end. The camshaft is 6 feet 2 inches above the ground, and therefore lifting it into the machine required approximately 5,392 ft-lb of work. To remove it and work on the cams would require it to be lifted down, stripped down, the cams (60 lb or 27 kg each) to be carried 75 feet (23 metres) to the forge at the other end of the battery terrace (Figure 378), the repairs to be carried out and the whole assembly to be rebuilt and replaced. If the repairs were carried out to the cams without stripping down the shaft then the whole combined weight would have to be manhandled.

Assuming the whole shaft was lifted, this would have required each end to have been supported, and lifting the assembly would require a lift of nearly 440 lb (200 kg) at either end. This is clearly too much for 2 or even 4 men to carry out unaided, but the use of a duplex tackle would reduce the required pull to 110 lb (50 kg) per man (for a 4 man team), and a triplex arrangement would require a manageable 73 lb (33 kg) per man. The work done by each of 4 men would be 1,348 ft-lb, again a manageable task.

Figure 378. The probable forge at the Young Australian Battery site.

These results indicate that some tasks in battery construction were hard work, particularly handling and erecting the heavy timber frames and the larger items of machinery. The Young Australian Battery is a light to mid-weight unit (565 lb stamps), in a very different class to the heavyweight Homeward Bound (1030 lb stamps), and yet these figures show that some very heavy weights needed to be handled in both cases. These weights would have been well beyond the capability of one or two men simply working unaided, but by using even the simple equipment available at the time, such as the block and tackle, the tasks were achievable.
The Working Environment

Most battery houses were typically constructed from an unlined timber frame clad with corrugated iron. The surviving mills, Callery’s at Macraes Flat (Figure 379), the Coromandel Government Battery, Sawyers Battery at Thames and the Lillis Battery are all of this form. Numerous historic photographs show similar structures, with great variation in size and layout but little variation in basic construction. The role of the battery house was to protect the plant from the weather at the cheapest cost, and the more substantial industrial buildings seen in many towns and cities of the time were generally absent from the goldfields.

Figure 379. The corrugated iron battery house of Callery’s Battery (site 142/161) at Macraes Flat.

The geographical range of the New Zealand stamp mill is large, from the cold and damp forests of Fiordland, through the hot-and-cold continental climate of Central Otago, to the wet sub-tropical Coromandel Range in the north. Working in an uninsulated corrugated iron shed in these climatic extremes would have been at times challenging, as the iron has no insulating properties (Thomson 2005: 61). In the Otago mountains water supplies would often freeze in the winter, and it was not unknown for the tables to freeze, delaying the last wash up until the following spring. In a steam powered battery some heat would be present, but most of these mountain batteries were water powered. In these situations work would be suspended over the winter (eg AJHR 1880 H26: 26; Otago Witness, 7 June 1884: 13).

The living conditions of the workers were often similarly basic. While this subject is beyond the scope of this thesis, it can be noted that various archaeological excavations and surveys that have included the communities associated with hard rock mines (eg Hamel 1994b; Petchey 2005a; 2006a) have found the workers’ huts to be small and simple. Building insulation if it existed consisted only of sacking or tussock, and there was no running water, electricity or other ‘modern’ comforts. Heating was by open fire or small coal range, and light was provided by candle or paraffin lamp.

The Sensory Experience: Sound & Smell

Mate (2010: 289) in her study of the industrial landscape at Mount Shamrock in Queensland commented that sensory perception, experienced visually and through touch, hearing and
smell, is one feature of any landscape. The visual aspect of landscape is generally given the greatest emphasis (Rainbird 2008: 263, quoted in Mate 2010: 289), but in a working mining context sound and smell would have been dominant (Mate 2010: 289).

**Sound**

Inside the battery houses the sound was probably quite literally deafening, but there are few recorded references to this noise, and there is no record of workers wearing any kind of hearing protection. Neither Stan Stephen’s reminiscences of working at the Snowy River Battery (Stephens n.d., 1986) or J.B. McAra’s account of the Waihi mines and Victoria Battery (McAra 1988) make mention of the noise. However, at a wider scale there are several references to the all-encompassing sound of the batteries in mining towns such as Black’s Point and Thames (Latham 1984; Weston 1927: 70). It is an often-told story that people in these mining settlements got so used to the noise that they could not sleep when the batteries stopped on Sundays (King 2004: 208). Mate (2010: 290) has made the additional observation that when the stamps ceased working, it could also mean a lack of work and income to a mining community, and therefore the absence of sound could have a profound social meaning.

During the late nineteenth century there was no way to objectively measure noise levels in working batteries, but today there are a number of operational preserved, restored or recreated batteries in New Zealand, and noise levels in several of these were measured using a digital sound level meter. Measurements were taken at the Black’s Point Museum stamper, Mitchell’s Gully Goldmine (running slowly and erratically when measured), the Government Battery in Coromandel and the Hauraki Prospectors’ Association Battery in Thames (Table 56). In each case the noise levels were taken standing beside the tables, a location where battery workers would typically have spent some time, and in each example every time a stamp dropped it generated approximately 100 decibels. As the majority of historic batteries had 5 or more stamps, up to 200 at Waikino, and each stamp was dropped 70 to 100 times a minute, the resultant cacophony can only now be imagined.

**Table 56. Noise measurements taken in operating stamper batteries in 2011.**

<table>
<thead>
<tr>
<th>Battery</th>
<th>Stamps</th>
<th>Weight</th>
<th>Drop</th>
<th>Drop/min</th>
<th>dB(A)</th>
<th>dB(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitchell’s Gully</td>
<td>4</td>
<td>250 lb</td>
<td>6 in.</td>
<td>45</td>
<td>83.6</td>
<td>87.6</td>
</tr>
<tr>
<td>Blacks Point</td>
<td>5</td>
<td>650 lb</td>
<td>6 in.</td>
<td>60</td>
<td>98.6</td>
<td>106.7</td>
</tr>
<tr>
<td>Hauraki Thames P.A.</td>
<td>5</td>
<td>1047 lb</td>
<td>5 in.</td>
<td>82</td>
<td>98.8</td>
<td>100.5</td>
</tr>
<tr>
<td>Govt. Coromandel</td>
<td>5</td>
<td>1030 lb</td>
<td>6 in.</td>
<td>70</td>
<td>103.4</td>
<td>108.6</td>
</tr>
</tbody>
</table>

Of note was the fact that measurements taken at the Hauraki Prospectors’ Association battery 12 feet from the stamps (beside the tables) and 25 feet from the battery (beyond the tables and Wilfley table) differed by only 2 decibels. Both readings were within the building (corrugated

---

37 Dick Smith Model Q 1362, with a range of 40dB to 130dB SPL, with A and C weighting.
iron over a timber frame), suggesting that noise levels within working battery buildings did not significantly decrease with distance from the machinery.

Current New Zealand Health and Safety in Employment Regulations (Department of Labour 1996) require employers to take all practicable steps to ensure that no employee is exposed to noise above the following levels, whether or not the employee is wearing a personal hearing protector:

- Eight-hour equivalent A-weighted sound pressure level, $L'_{Aeq,8h}$ of 85dB(A); and
- Peak sound pressure level, $L'_{peak}$ of 140 dB.

These standards are in place because prolonged exposure to any sound over 85 dB will cause permanent hearing damage (www.dangerousdecibels.org), and as the above table shows only the lightest of the stamps measured (which were mounted in the open and were running slowly) were close to this level. Although the sample size was small, it clearly shows that the noise in a working stamper battery was almost certainly in every case loud enough to cause permanent hearing damage in all those who worked there. Although the annual Mines Department reports comment on serious and fatal accidents they have little to say about occupational injuries such as deafness, but it is almost certain that every battery worker employed for more than a few months would have had damaged hearing.

**Smell, Vapours & Dust**

Geraldine Mate (2010: 290) used the term ‘smellscape’ to describe the variety of smells and odours that mine and battery workers would have experienced. Almost all of the archaeological remains of stamp mills discussed in Chapters 8 and 9 are now in forest and mountain environments, and can reasonably be described being in the fresh air. However, when working many of the processes used in the mills produced odiferous and/or dangerous fumes, and while these can no longer be experienced, there is ample archaeological evidence for their past presence.

**Mercury**

Mercury amalgamation was probably the most common form of gold recovery process, and the final stage of this process was the retorting of the gold/mercury amalgam to vaporise and drive off the mercury. As already discussed in Chapter 9, parts of mercury retorts are present on a number of sites (Figure 380). Water-cooled condensers were used to recover the mercury, but some fumes would certainly have escaped. Prolonged exposure to mercury vapour can lead to chronic mercury poisoning, the symptoms of which are loss of appetite, salivation, gingivitis, nutritional disturbances, increasing renal damage and anaemia (Encyclopædia Britannica).
Furnaces

Various forms of furnace were used, as discussed above in Chapter 9. These could produce pungent and toxic fumes, and G.H.F. Ulrich (1875: 87) reported that the furnace at the Phoenix Battery had ceased to be used “on account of the fumes being unbearable and dangerous to the men working in the building.” In 1926 William Brown died after inhaling fumes from a mixture of acid and concentrates from the Edwards Roaster at the Snowy River Battery (AJHR 1927 C2: 15). In some places the toxic by-products of some furnaces are still apparent. The 1934 Edwards Roaster furnace (site L31/83) at the Alexander Mine stands in regenerating beech forest (Figure 381), but nearby piles of roasted battery concentrates still bear little vegetation growth despite it being nearly 80 years since the furnace shut down (Figure 382). Other nearby examples are the Prohibition Mill (site L31/47) and Snowy River Battery (site L31/37) at Waiuta, which both have extremely high arsenic concentrations around the former furnace locations (Haffert & Craw 2008).
Dust

Dust was the greatest single health hazard in underground mines and stamp mills that used dry-crushing (McAra 1988: 251). Miners’ phthisis or silicosis was caused by the intake of sharp fine particles of siliceous dust into the lungs, where they worked their way into the tissue. Fibrous masses grew around the embedded dust, reducing the effective area of the lung as tissue was destroyed. Shortage of breath was the first symptom, followed by chronic bronchitis. Other complications such as infections or tuberculosis could also occur, compounding the problems. The condition was often fatal, although death could be either fast or lingering (Birrell 1998: 139; Latham 1984: 355-356; McAra 1988: 253). The hazard of quartz dust was addressed mainly through the adoption of water spray on underground drills and wet crushing in stamp mills. Mills that had used dry crushing were generally changed to wet processing; the Victoria Battery near Waihi was converted in stages between 1900 and 1902 (McAra 1988: 117, 126).

However, despite the importance of the issue at the time, dust is a hazard that has left little or no archaeological evidence, other than the almost universal use of wet crushing indicated by the pipes and water inlets into the mortar boxes of stamp mills.

Cyanide

The widespread use of the cyanide process after the 1890s is well represented in the archaeological record, and there are a number of reports of men and boys dying from exposure to cyanide, especially after falling into the vats. An early fatality occurred at Cassel’s plant at Karangahake in 1892 when a man named James Tagart, fell into a vat
containing solution of cyanide of potassium, and despite being quickly removed died about five minutes later (AJHR 1892 C3A: 16). Another death occurred at the Snowy River Battery (Figure 383) in 1916 when a 15 year old boy, Albert Riley, was killed when he was left in sole charge of the cyanide works (in breach of the Mining Act) and slipped into a tank of cyanide solution (Latham 1984: 323).

Figure 383. The Snowy River cyanide plant (site L31/37). The site of the death of 15 year old Albert Riley.

Summary

As the above discussion has shown, the archaeological evidence of the workplace is a combination of original design and construction (with decisions made by engineers and managers) and subsequent repair and modification (with decisions made by many different people, from the battery engineer down to the man on the end of the hammer). It is the combination of the archaeological evidence of the working life of the mill as well as its original design and construction that can inform us about the working lives of the millmen.

The battery was an extremely manual workplace, where basic tools and lifting equipment were used by men hardened to heavy labour. Large and heavy mills, such as the Homeward Bound and Victoria Batteries relied on manual labour, and even lightweight stamp mills had heavy parts, but only small workforces and limited facilities for dealing with them. Heavy lifting was by block and tackle or jack, but ultimately relied on muscle power. Repairs and maintenance were an everyday requirement of operating mills, and these tasks were sometimes carried out using good quality spare parts, but in operations with little capital backing many improvisations were made. Recent work in America by White (2010) at the
Skidoo Mill in Death Valley, California found similar evidence of pragmatic repairs in an ageing mill.

The workplace environment was harsh by today’s standards, with noise, dust, fumes, unshielded machinery and extremes of temperature all present. Noise levels were unacceptable by today’s industrial safety standards, but so constant that they received little contemporary comment. Most battery workers were probably effectively deaf after a few months or years of work in the mill. Materials such as cyanide and mercury were toxic, but again despite the hazards, and the occasional death, they were accepted risks. The same can be said for the various furnaces and roasters that were used. Occasionally the noxious fumes received comment, such as Ulrich’s comment in 1875 that the Phoenix furnace had been shut down for this reason, but experiments with furnaces continued well into the 1930s.

The hazard that received most contemporary attention was the quartz dust that caused silicosis (miners’ phthisis). This affected both miners and battery workers, and while to the nineteenth century mining community deafness was acceptable (a man could still work), a slow incapacitated death from lung failure was something that caused comment and demanded a response. A Royal Commission did examine the issue, but it was not until 1915 that a miner’s pension of £1 a week was established (McAra 1988: 251).

However, one cannot equate modern attitudes towards the workplace environment with historic attitudes. While the noise levels in a stamp mill might be the easiest environmental condition to replicate now, not only was this not commented on greatly at the time, but it is highly likely that the noise had a different social meaning to today. As Mate (2010: 290) very importantly observed, to a nineteenth century mining community silence might simply mean that the battery had shut down, and there was no work. This was a devastating situation in a world with no welfare system, where working men had to provide for their wives and families. Miners’ strikes in Reefton in 1896 and Waihi in 1912 caused great hardship to all those involved (Latham 1984: 192-193; McAra 1988: 259). To modern eyes the stamp mill was a hard, noisy, dangerous and sometimes smelly place to work, but most importantly, it was a living for the workers.
Chapter 12
Conclusions

The archaeological remains of stamp mills in New Zealand stand as testimony to the international nature of the late nineteenth century goldfields. Machines made in New Zealand, Britain, America and Australia all survive, and show a mixture of design features and influences that evolved since the machine first took on its ‘modern’ form in 1850s California. While the basic form and function of all of the surviving machines is the same, there is immense variety in detail and no two machines or their associated milling circuits are identical. This variety has allowed a detailed consideration of the milling technology that came to New Zealand at a number of scales, in line with current theoretical approaches in historical archaeology that emphasise both global and the local aspects of ‘modern world’ sites. At the global scale this study has identified the main sources of technological innovation, the mechanisms of transmission, the role of international companies and the role that New Zealand itself played in the process of technology transfer. At the local level the roles of the small local mining companies has been considered, local pragmatic adaptation and repair and local innovation have been identified, and finally all of this research has been used to consider the experience of the individual worker.

The key to this research is the use of the contemporary nineteenth- and early twentieth-century technical literature to understand and accurately describe the archaeological remains of New Zealand’s stamp mills. A more conventional approach, that simply compared the New Zealand examples to surviving archaeological examples of stamp mills overseas, would have been a useful comparative exercise, but could not fully answer questions as to where particular designs came from, why they were chosen, and what their advantages/disadvantages were. Understanding, as opposed to simply describing, the engineering of the stamp mill is therefore at the heart of this thesis. This has shown that a detailed description and understanding of the finest detail of an industrial site has the potential to place that site in any context, from the experience of the individual mill worker up to the actions and decisions of international companies. This approach takes Mortimer Wheeler’s (1956: preface) 60 year old challenge that “the archaeologist is digging up, not things, but people,” and shows how even the most technical and ‘thing-orientated’ Industrial Archaeology can address the human experience.

Technology

New Zealand’s gold mining industry was a small but active member of a very large international industry, and the technology adopted here almost all originated elsewhere. The spread of ‘Californian Mill’ to all of the world’s major goldfields during the late 19th century was accompanied by a continuous evolution, with successful new design features then being transmitted internationally. The opening up of global communications in this period was crucial to the spread of technology and the growth of international business, and gold mining was an active player in this expansion. Stamp mill technology came to New Zealand both in the physical importation of mill machinery, and in designs that were then manufactured here. Direct importation initially came from the closest neighbour, Australia, and later from America and Britain. As demand for machinery grew local manufacture began near all of the main goldfields, and A.&G. Price of Thames stand out as an early adopter of imported
designs, most notably the American-patented Pelton wheel that was used to power innumerable stamp mills after its introduction in 1884.

However, despite this apparent dependence on imported technology, the New Zealand mining industry was not entirely ‘technologically dependent.’ While the largest mills were established by international (generally London-based) companies, and often used expensive imported machinery, some degree of local agency in the selection and set up of these mills was apparent, and local promoters such as David Ziman and W.J. Farrell played key roles in attracting overseas investment. The smaller locally financed mining companies used a far wider selection of equipment, some imported, some locally manufactured, and often purchased second-hand from failed ventures. A much greater degree of local agency is apparent in these mills, as the groups or individuals involved selected their machinery on a number of criteria, amongst which price and availability were often uppermost (although some memorable expensive failures also occurred). Archaeological evidence of pragmatic modification and repair is often visible in this machinery, with some completely worn out mills being kept in service by labour intensive, but cheap, repairs. Innovation both successful (the B&M Agitator) and unsuccessful (Ashcroft’s Crusher) is also present. The Bendigo Battery site, with its locally-manufactured machinery with up-to-date features, and cyanide tanks made from the ubiquitous corrugated iron of colonial New Zealand, illustrates how the local mining industry had adopted international technology for use in a local context.

The model that the archaeological evidence supports best is not New Zealand’s ‘technological dependency,’ or even ‘technological sovereignty,’ but ‘technological participation.’ While acknowledging that New Zealand was a small player, and that most technological innovation did occur overseas, the local industry still took an active part in the development and deliberate selection of mining technology. The electrical installation at Bullendale at 1885/1886 was not necessarily an innovation, as it was contemporary with similar developments elsewhere in the world, but in this context it proves that New Zealand was most definitely participating rather than following.

**The Workplace**

The stamp mill was developed as a mechanical way to do more work than a man alone could do, but men were always essential to run and maintain the machinery. By examining in detail that machinery it has been possible to consider the human experience of the workplace. The detailed site descriptions and measurements that were used to assess aspects of mill technology (such as the calculation of stamp weight) can be used to determine the loads that men had to move to build, service and repair the machinery, which were often very heavy even in the lightest mills. Small forges represent the workshops of a period before power hand tools existed. The small number of reconstructed stamp mills that operate in New Zealand provide an opportunity to measure at first hand the noise levels that millmen had to endure on a daily basis, which are without fail in excess of modern industrial safety standards, and mercury retorts and still-toxic waste dumps illustrate the poisonous environmental conditions that existed.

However, while research shows that the stamp mill was a noisy and dangerous place to work, it must be remembered what it represented: paid work. To modern sensitivities and by modern workplace standards the nineteenth century stamp mill might appear to have been an unacceptable working environment, but in the nineteenth century the Welfare State had not
even been thought of, and continuous paid work was vital for a man and his family. A noisy mill was a working mill, and for many mining settlements when the noise stopped the town died.

Future Research

As outlined in Chapter 1, this research had necessary limitations, and a number of avenues of future research would be very rewarding. In particular, a comparison of the New Zealand archaeological evidence with that in America, Australia and Britain would be invaluable. The present research has considered the Australian influence on New Zealand technology on the basis of the Australian-manufactured machinery found here, and a comprehensive comparison with the Australian archaeological record would determine whether more complex interactions were at play.

This thesis considered each battery site largely as a stand-alone item, but obviously every site exists within a large and complex archaeological landscape. Geraldine Mate’s recent work at Mount Shamrock in Australia, has identified industrial and domestic ‘sub-landscapes’ in that place, one of the sub-landscapes being the mill site (Mate 2010: 304). In New Zealand recent work by Jessie Garland has identified a ‘medical landscape’ based on archaeological investigation of the St. Bathans cottage hospital, which shares many parallels with the industrial landscape, including the importation and use of innovative technology, local community demand, the role of trained professionals, and the role of training schools in New Zealand and abroad (Garland 2012: 156). There is therefore great potential for the on-going archaeological study of numerous parallel and interlinked social and industrial landscapes, which despite their apparent disparate natures were all connected in forming the social fabric of nineteenth century New Zealand.