The archaeological interpretation of the New Zealand stamp mill

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The stamp mill (or stamper battery) is the most commonly surviving item of machinery on the New Zealand goldfields, and machines can be found in all of the old major hard rock mining areas from Coromandel to Fiordland. Each machine was the product of a series of human decisions in response to the requirements and constraints of each mine site. Mine owners, managers, engineers and workers all had an input into creating the machines that now constitute the archaeological record. This paper presents a standardised terminology for describing stamp mills, based on contemporary engineering sources, and then uses the United Goldfields Battery as a case study to show how an archaeological examination of stamp mill engineering can also shed light on the roles that people played in their creation and operation.

INTRODUCTION

The stamp mill (also known as the stamper battery, gravitation stamp mill and Californian 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). 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.

Many, if not most, of these machines have been recorded by archaeologists, but often with varying degrees of accuracy and detail in terms of their engineering and component parts, and with a similar variation in the degree of interpretation of their technology, modification and usewear. The stamp mill was generally the largest and most robust part of the battery equipment ('stamper battery' was sometimes used to refer to the overall processing plant that included the stamp mill), and consequently is the most commonly surviving large artefact associated with the gold milling process. This good survival rate makes it an excellent subject for archaeological study. Work in America (White 2010) and Australia (Mate 2010) has begun to explore some of the meanings in the archaeology of the stamp mill, respectively exploring strategies used to keep an old mill in use, and the mill as a workplace within a wider social/industrial landscape.

The present paper starts by presenting a standardised terminology and describes the basic engineering of the stamp mill, based both on contemporary engineering sources and a detailed site survey of surviving mills in New Zealand (Petchey 2013). This is intended to enable battery sites to be accurately and consistently described from an archaeological perspective. The paper then goes on to consider the archaeological interpretation of the stamp mill, with a focus on several distinct aspects: the identification of particular design features; the chronology of these features; construction choices; and repairs and modifications. It particularly asks how aspects of human agency can be examined through an archaeological examination of the mill; what decisions were made regarding mill construction and operation; and why these decisions were made. The surviving United Goldfields Battery at Macetown in Otago is used as a case study to illustrate these approaches.

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Figure 1: The Homeward Bound Battery beside the Richburn near Macetown.

BASIC TECHNOLOGY

The gravitation stamp mill was in essence a very simple machine. It was a hammer mill where heavy weights (stamps) were raised and then dropped onto ore, to reduce that ore to the consistency of sand to enable any bullion (gold and silver) that it contained to be freed and saved. The crushing energy available was directly related to the weight of the stamp, the height to which it was raised, and the number of drops made per minute.

The gravitation mill was possibly in use in the Roman mining industry as early as the first and second centuries AD, and it was in widespread use in Europe by the sixteenth century (Agricola 1950:312; Burnham 1997:332-334; Wilson 2002:21-22). This basic stamp mill evolved into the more developed 'Californian stamp mill' on the Californian goldfields in the aftermath of the gold rushes of the late 1840s and early 1850s. The distinctive features of this mill were the use of revolving iron stamps and a camshaft with two-lobed cams, which replaced the square wooden stamps and large cam barrel of earlier European and Cornish stamps (Del Mar 1912:4-5; Philips 1867:172). The Californian mill then spread to the other late nineteenth-century goldfields, notably Australia, New Zealand and South Africa. The mill continued to be refined and developed, and in particular the maximum stamp weight increased from about 900lbs (408kg) in the 1860s to over 2000lbs (907kg) in the 1910s, with 1250lb (567kg) the maximum used in New Zealand (Caldecott 1909:58; Del Mar 1912:11, 12; Gowland 1914:202; Phillips 1867:173; Truscott 1923:137). Stamp weight and the number of stamps were used to describe the size of any particular mill.

Stamp mills that had a powered down stroke were developed, but it was the mechanically simple gravitation stamp mill that found almost universal favour until the early twentieth century, when it was gradually replaced by ball and tube mills.

STAMP MILL ANATOMY AND TERMINOLOGY

Several guides to general mining terminology for archaeologists have been produced (e.g. Pearson and McGowan 2000; Ritchie and Hooker 1997), and these provide an excellent source for the overall description of gold mining sites. The detailed study of any one aspect of mining or milling, the stamp mill in the present case, requires a more detailed and specialist technical vocabulary, which is available from contemporary mining engineering sources.

A standardised technical terminology was developed for the stamp mill, albeit with some variation between countries and some local use of vernacular terms. Three standard works are primarily used here: Truscott (1923) is a British source; Richards (1906) is American; and Gordon (1894, 1906) is the main New Zealand text. Table 1 and Figure 2 set out the terms for the main components based on these sources, with variations from other authors also noted (Del Mar 1912;

Table 1: Stamp mill terminology, showing variations in terms used between various sources.

Truscott (1923)	Richards (1906)	Gordon (1894, 1906)	Other variations
Mud sill	Mud sill	Mud sill	-
Streak sill	Cross sill	Cross sill	Battery sill
Battery post/ King post	Post	Battery post	-
Mortar block binder	Buckstaff	-	-
Mortar block	Mortar block	Mortar block	Battery block
Top guide timber	Upper guide	Guide	-
Bottom guide timber	Lower guide	Guide	-
Battery post binder	-	-	-
Mortar box	Mortar	Mortar	Battery box, Coffer
Screen	Screen	Screen	-
Die	Die	Die	-
Shoe	Shoe	Shoe	-
Head/boss	Boss	Stamp head/ socket	Boss-head
Stem	Stem	Stem/stamp shank	Shank, stalk
Tappet	Tappet	Tappet	Stud, disc
Cam shaft	Cam shaft	Cam shaft	-
	Collar	Collar	-
Cam-shaft bearing	Cam shaft box	Plummer block or Cam shaft bearing	Cam-box
Cam	Cam	Cam	Wiper
Driving-pulley	Pulley	Battery pulley	Bull-wheel, Cam-shaft pulley
-	Main shaft	Intermediate shaft or Line shaft	Countershaft
Belt tightener	Tightener	-	-
-	-	Jack shaft	-

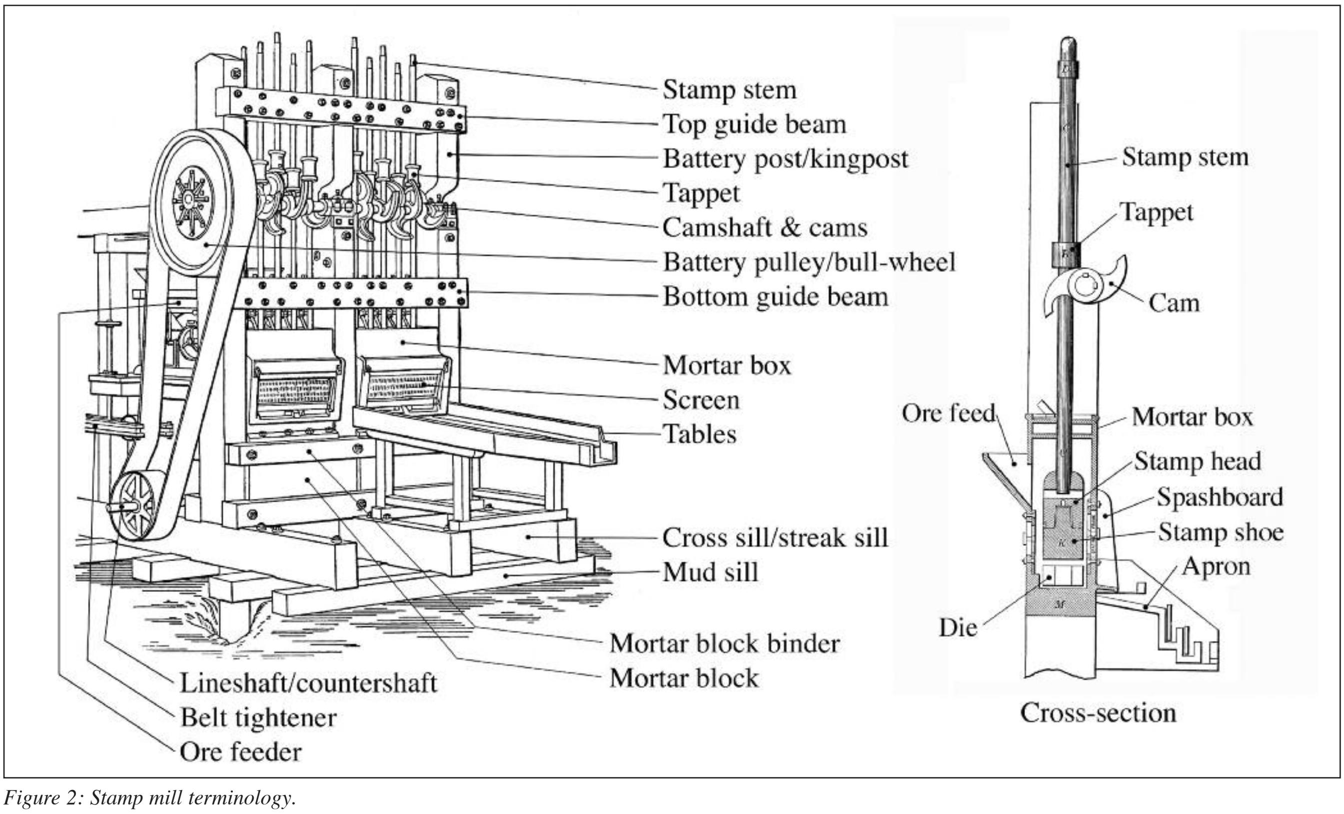

Figure 2: Stamp mill terminology.

International Library of Technology 1902; Louis 1902; Mine and Smelter Supply Co. 1912; *Otago Witness* 18 June 1864:16; Phillips 1867; Ulrich 1875). The use of the same terminology for archaeological observations allows both good comparison between sites and accurate description and analysis of any single site.

Despite the degree of consistency in terminology, almost every single part within the stamp mill did exhibit variation in detail for a variety of reasons, including change over time, operational requirements, geographical variability, and differences between manufacturers. The significant large-scale differences in mill layout were in the number of stamps, the weight of those stamps, and the frame design, while smaller detail differences included the design of the tappets, cams and mortar boxes. Most of the variations in individual components occurred without changing their basic function, and later components could often be incorporated into older machines. This is useful when analysing and comparing several sites from an archaeological perspective, because all gravitation stamp mills are functionally almost identical although widely variable in detail. It is this variability that allows different responses to geographical, geological, economic and other constraints to be considered.

The frame

The stamp mill frame consisted of two main elements: the foundations and the superstructure. The foundations were either timber or concrete, while the superstructure was either timber or iron.

Foundations

When timber foundations were used the main stamp mill frame and the mortar block (the block that supported the mortar box) were generally two separate structures, in order to isolate the vibration caused by the falling stamps. There were two main exceptions to this practice; occasionally when ground conditions were poor a horizontal mortar beam was laid across the timber foundations (e.g. at Johnston's United Battery in northwest Nelson); and when concrete foundations were used it was found that the two structures could be combined (e.g. the 1910 Bendigo Battery at Waiorongomai has a single monolithic concrete foundation) (Richards 1906:148; Truscott 1923:143-144, 147).

Conventional timber stamp mill foundations consisted of a cribwork of heavy beams; the bottom beams that ran in line with the stamps were termed 'mud sills,' and the upper beams that ran across the line of stamps (and upon which the battery posts were mounted) were termed 'cross sills' (Figure 2). There could be one or more layers of each, depending on the ground conditions, and there could be from two to six mud sills in each layer.

Concrete began to be adopted for mill foundations from the 1890s, and became common (but not ubiquitous) in the twentieth century. Initially it was thought that the concrete would not withstand the vibration from the stamps, nor the stamps the 'shivering rebound' from the concrete, but 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 and Bremner 1900:180; Truscott 1923:143). Concrete could be used for the mortar block, for the main mill foundations or for both combined. It was widely adopted in New Zealand stamp mills, and a number of archaeological sites have evidence of the transition from timber to concrete, with early construction in timber and later additions in concrete (e.g. the 1908–1938 Snowy River Battery at Waiuta and the 1897–1952 Victoria Battery at Waikino).

UPPER FRAMEWORK

When timber was used for the upper framework the majority of designs fell into four main categories: A-frame, braced vertical-post frame, trestle-frame and knee-frame (Figures 3 and 4). This is one area where the contemporary engineering descriptions and archaeological observations do not completely align. In particular, a number of authors described mills with vertical battery posts and diagonal timber braces as 'A-frame' mills (Figure 3c) (e.g. Richards 1906:157), whereas the surviving mills include a number that have a 'pure' A-frame form (Figure 3a), and as such these two forms are archaeologically differentiated from each other and identified here as 'A-frame' mills and 'braced vertical post' mills.

A-frame mills

The A-frame mill has pairs of battery posts that are widely mounted at their base on the cross sill, and are inclined towards each other to meet at the apex to form a triangle, and with a beam then mounted across the 'A' to carry the camshaft bearings (Figure 3a). The triangular A-form of the frame is geometrically rigid, and so A-frame mills need no other bracing. In New Zealand the form appears to have been most commonly adopted in the South Island (all of the surviving examples are in the south), for mills with up to 820 lb (372 kg) stamps. In general it appears to have been an early form of frame that was in common use in the 1870s, with the last surviving example at the United Goldfields Battery at Macetown having been erected in the 1910s, although as discussed below this was almost certainly a re-used frame.

Braced vertical post mills

Braced vertical post mills have heavy vertical battery posts that are braced fore and/or aft by diagonal timber braces that run between the post and the cross sill (Figure 3c). The braces are often held in compression by iron rods that run parallel to the timber. The camshaft is mounted on the battery post, which also carries the upper and lower stamp guides. The location of the braces is generally determined by the direction from which the drive was taken, as the braces had to support the structure against the pull of the drive belt. This form of timber frame was used for a wide range of stamp weights (up to 1030 lb (467 kg) at the Government Battery in Coromandel) and appears to have been used for a long period (surviving examples date between c.1881 and 1903).

Trestle frame mills

The Trestle-frame mill carries the camshaft on a large horizontal beam that is in turn supported by two vertical posts that usually incline inwards slightly towards the top (Figure 3b). Long iron rods run between the camshaft beam and the cross sill, to hold the structure tightly together. The vertical battery posts are generally relatively lightweight as they only support the stamp guides, and do not carry the weight or loading of the camshaft. This form of frame was also used for a long period, as the 1880 Printz's Battery in Southland (that was possibly manufactured in the late 1860s) and the 1942 Currie's Battery in Otago are both of this pattern. It was also used for a range of stamp weights, from the 490 lb (222 kg) Canton Battery to the 800 lb (363 kg) Invincible Battery.

Knee-frame mills

The knee-frame mill has heavy vertical battery posts that are braced either fore or aft by heavy horizontal beams (Figure 4a). The camshaft is carried on the battery post, in the same fashion as the braced vertical post frame. The knee-frame was

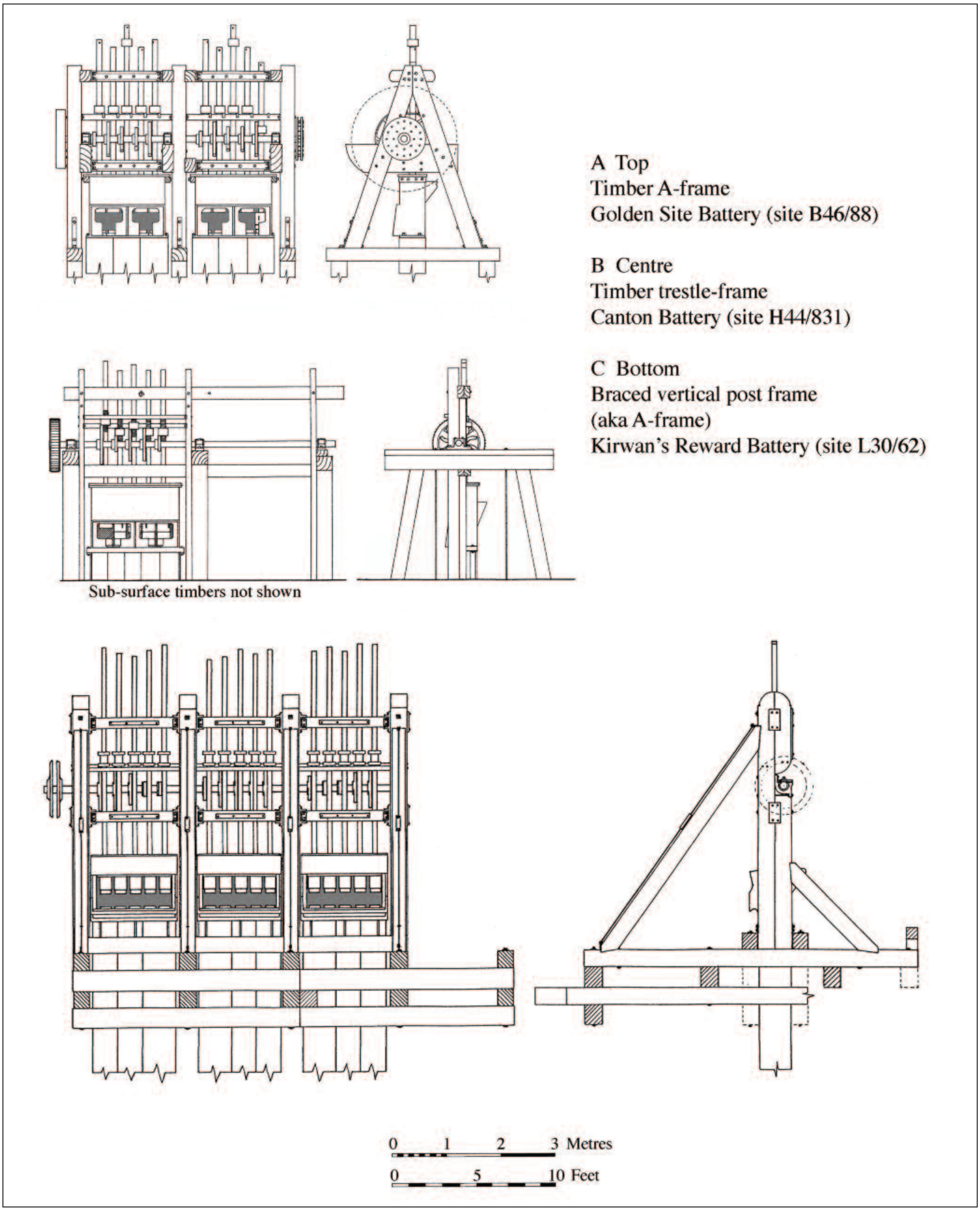

Figure 3: Stamp mill frame forms.

the favoured form of frame for heavy mills by the beginning of the twentieth century, and several contemporary authors only discussed this type (e.g. Gordon 1894:Figure 50; Louis 1902:234; Truscott 1923:147).

The only surviving example of the knee-frame mill in New Zealand is the Homeward Bound Battery at Macetown (Figures 1 and 4a), which is a back-knee frame mill with built-in ore bins. This mill was first erected at Waipori in 1899, and was moved to Macetown in 1910 (Appendices to the Journals of The House of Representatives 1909 C3:36, 1910 C3:33). It was manufactured by the Sandycroft Foundry of Chester, England, and is an almost exact match for mills illustrated by several contemporary authors (e.g. Louis 1902:238; Truscott 1923). The Homeward Bound has heavy 1120 lb (508 kg) stamps, and historic photographs of other heavy mills show that knee-frames were in common use in these large plants

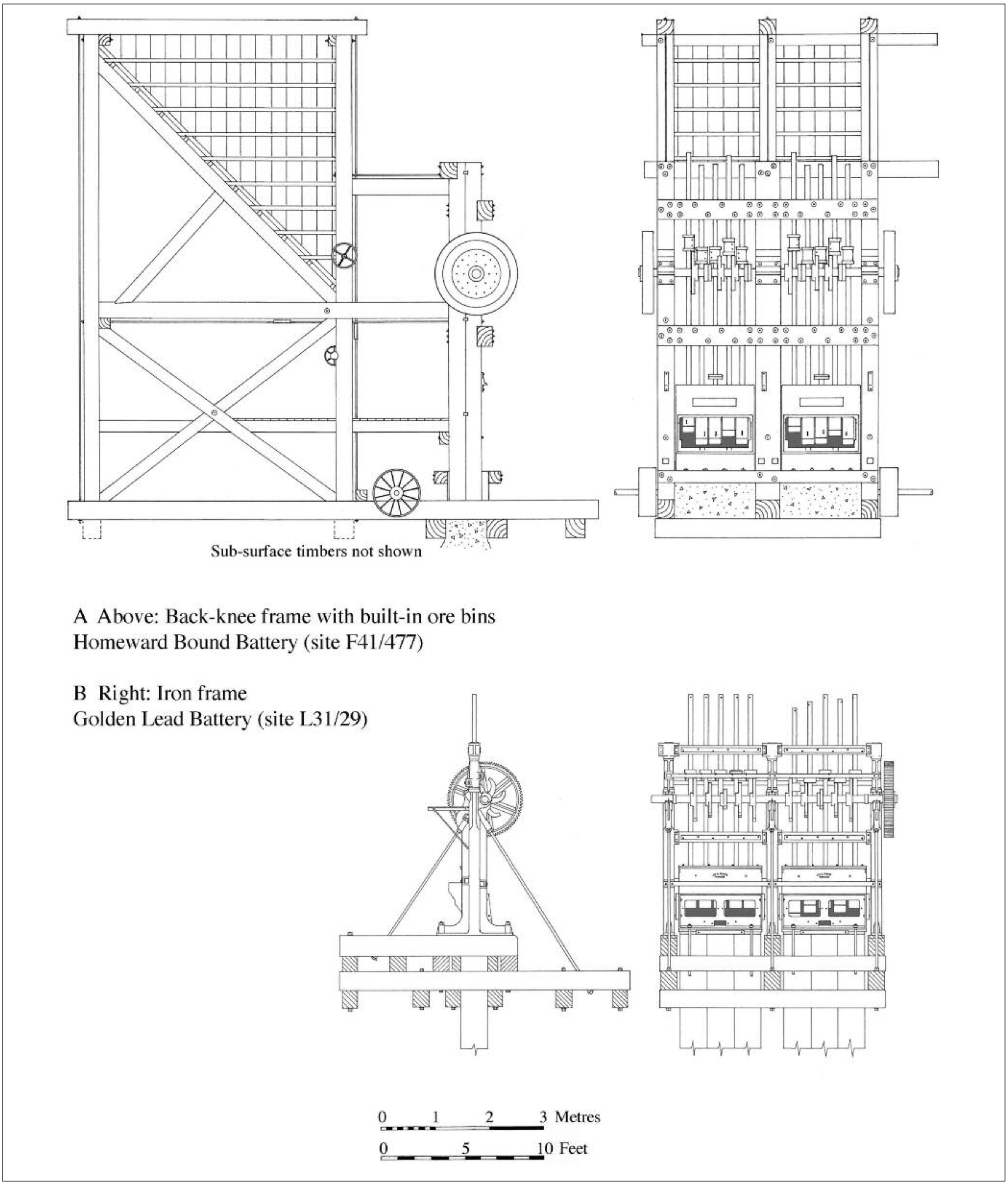

Figure 4: Stamp mill frame forms.

(e.g. Nathan 2010:62). The lack of survivors is probably due to the fact that the larger batteries were too valuable as sources of scrap iron to be simply abandoned.

Iron frame mills

Cast iron frames (Figure 4b) were in common use throughout the country, and those that escaped the scrapman have survived well because of the durable nature of the material. Although it would seem logical that iron would be more technologically advanced than timber, and would inevitably replace the latter, this was not necessarily the case. A number of the surviving cast iron mills are of relatively early manufacture (e.g. the 1871 Ajax Battery near Reefton), while timber continued to be used for very late mills because of its natural resilience (e.g. the 1903 Nugget Battery beside the Shotover River). The assumption that cast iron framed mills would be technologically advanced is also not borne out by the archaeological evidence, as many of these mills exhibit early technological details such as the use of screw tappets and bolt-on screens (both of which are discussed below).

Surviving iron mill frames were made in New Zealand (e.g. the Golden Lead Battery near Reefton, see Figure 4b), Australia (e.g. the Albion Battery at Terawhiti), America (e.g. the Welcome Jack Battery in the Coromandel) and England (e.g. the unprovenanced Bowes Scott & Western mill now at Waikino). Langland's Foundry in Melbourne was a particularly prolific supplier of early (1870s) cast iron mills to the New Zealand goldfields. Many of the mills of Australian and New Zealand manufacture show very similar stylistic features (see Figure 4b). In particular the battery posts have a standardised design, with square section lower portions, octagonal centre sections and round upper sections, topped by a squared off cap (that mounted the top stamp guide).

Miscellaneous mill forms

The 'standard' New Zealand stamp mill is a multiple of the five-stamp form (i.e. 5, 10, 15 stamps etc.) with each 'module' of five stamps falling into a single mortar box, but a number of other variations survive, in particular small one and two stamp prospectors' mills. These often had compact frame forms with timber or iron battery posts bolted directly to the sides of the mortar box. A form peculiar to imported US stamp mills was the four-post frame, which consisted of four timber posts bolted to a two-stamp mortar box (e.g. The Red Queen Battery in Figure 5d), or four cast iron posts on a five stamp mill (e.g. The Welcome Jack Battery on the Coromandel Peninsula).

COMPONENTS

The mortar box

The mortar box was the iron box within which the stamps dropped and the ore was crushed (Figure 5). The most common form in New Zealand is the five stamp box, although one, two, three and four stamp boxes also survive, and six stamp boxes are known from historical sources to have existed (e.g. *New Zealand Mines Record* VIII, 7:1905). Mortar box weight also increased as average stamp weights increased over time, as it was important that the box provided a steady base for the dies. Much of this extra weight was incorporated in the base thickness of the box. Other than basic size and weight,

Figure 5: Mortar box designs. A-Vertical bolt-on screen. B-Inclined slot screen. C-Sectional with vertical screen. D-Sectional 2 samp mill with slot screens.

there was a wide variety in design detail in boxes, but two main parameters are notable: the method of screen fixing, and the use of 'sectional' boxes.

Screens were affixed to the openings in the front of the mortar box (and back and/or side in the case of multiple-discharge boxes), and consisted either of wire mesh or perforated metal sheets. The size and density of the holes in the screens controlled the size of crushed particles that could pass out of the box. There were two main methods of mounting screens: either using frames that were bolted to the vertical front of the mortar box (Figure 5a), or using wooden frames that were located in inclined slots in the front of the box (Figure 5b). Inclined slot screens are known to have been in use in America from the 1860s (Phillips 1867:176), but the archaeological evidence in New Zealand is that vertical bolt-on screens were ubiquitous until the 1880s, after which inclined slot screens were increasingly adopted. A number of mortar boxes manufactured by A. & G. Price of Thames have embossed dates, and a pair made in 1875 have vertical bolt-on screen mounts, while five others made in the 1890s all have inclined slot mounts. Old boxes often continued in service, and the c.1910s ten-stamp United Goldfields Battery at Macetown has one box of each type (discussed further below).

'Sectional' mortar boxes were built up out of a number of cast and sheet iron sections that were bolted together (Figure 5c and 5d), and were designed to be disassembled for transport to remote or mountainous areas (International Library of Technology 1902:33; Raymond 1870:661; Richards 1906:164). They were in common use in New Zealand, with excellent examples at the almost adjacent Phoenix and Southberg's Batteries at Bullendale in the Harris Mountains of Otago. Some contemporary engineers thought that they were troublesome, as they often worked loose and leaked (Appendices to the Journals of The House of Representatives 1885 C2:3; Louis 1902:162-163).

Figure 6: Cam forms. A-Lightweight with keyway. B-Heavy duty with Blanton wedge mount. C-Key & keyway mount. D-Blanton mount.

The cam

The universally adopted form of cam in New Zealand was the two-arm cam (Figure 6), which raised and dropped the stamp twice for each rotation of the camshaft. The cam was designed using an involute curve, which produced a constant rate of lift to the stamp (Del Mar 1912:102; Louis 1902:202-203; Morison and Bremner 1900:159; Richards 1906:196). In the late nineteenth and early twentieth centuries an increase in crushing capacity was generally achieved by increasing stamp weight rather than drop height, and cam design reflected this. The robusticity of surviving cams varies greatly from lightweight thin arms (Figure 6a) to heavyweight arms with strengthening webs (Figure 6b). The tip-to-tip dimensions of surviving cams does vary (17.5 inches to 34 inches (444 mm to 864 mm) with most between 24 inches and 33 inches (610 mm to 838 mm)), but some of this range is accounted for by the clearances needed for larger diameter camshafts and stamp stems (due to the increasing stamp weights) rather than increased drop heights.

Another notable aspect of cam design is the method of fixing the cam to the camshaft. Most cams are fixed using conventional iron keys that fit into a keyway cut into the cam hub and shaft (Figure 6c). However, in 1893 Edward Blanton patented a new fixing method that used a curved metal wedge that was self-tightening against the rotation of the camshaft (Figure 6d) (Blanton 1902; Clark 1904:78; International Library of Technology 1902:21; Louis 1902:198; Richards 1906:193; Truscott 1923:152). The Blanton cam had numerous advantages, and in particular it was easier and quicker to remove and remount than conventional keyed cams (Richards 1906:194). The Blanton cam is found on a number of better-engineered post-1893 surviving stamp mills in New Zealand, including the large Homeward Bound Battery at Macetown (Figure 1) and the small two-stamp Eureka Battery at Skippers. The known patent dates of the design provide a useful *terminus post quem* for the manufacture of these machines. Of particular note are the Blanton cams at the Bendigo Battery at Waiorongomai that were manufactured by A. & G. Price of Thames, which are the only known New Zealand made examples (Petchey 2013:225).

The tappet

The tappet was the collar affixed to the stamp stem upon which the cam acted to lift the stamp. There were three main types of tappet employed in New Zealand: the plain collar tappet (secured by a key); the screw tappet; and the gib tappet (Figure 7). All were adjustable so that the stamp drop height could be set and to take account of the ongoing wear to the shoes and dies, and many were made double-ended so that they could be reversed when one face became worn.

Plain collar and screw tappets (Figure 7a and 7b) were used in very early stamp mills in New Zealand, and continued in use in light- and mid-weight (up to 700 lb (317 kg)) mills until the early twentieth century (*Otago Witness* 18 June 1864:16; Petchey 2013). However, they were known to have weaknesses; screw tappets in particular could work loose and the thread would then wear rapidly (Rickard 1898:16). Consequently, for heavier stamps (700 lb to 1250 lb (317 kg to 567 kg)) the gib tappet (Figure 7c) was used. This was a reversible cast tappet that was secured by a wrought iron or forged steel gib and two or three tapered keys. It was quick and easy to adjust and remained tight in use (Gordon 1906:380;

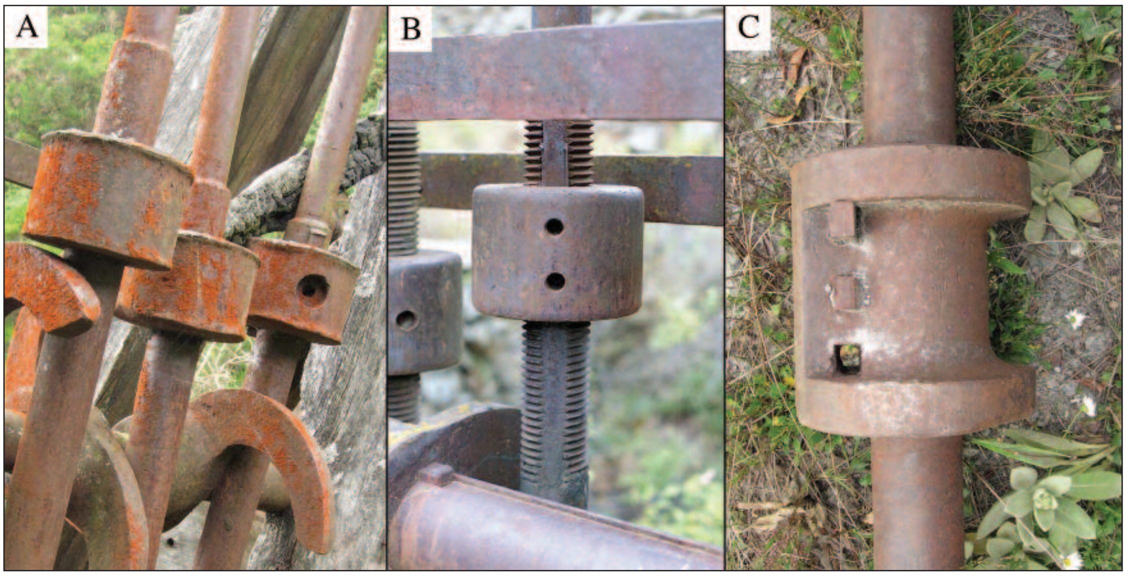

Figure 7: Tappet forms.
A-Plain collar tappet.
B-Screw tappet.
C-Gib tappet.

Richards 1906:189). The 'Californian' or 'Wheeler' gib tappet was invented by Zenas Wheeler, and was widely used in the United States of America by 1870, although surviving New Zealand examples only date to the 1890s and later (Louis 1902:172; Paul 1895:528; Petchey 2013; Raymond 1870:658; Richards 1906:188).

Drop order

The drop order was the order in which the stamps in each mortar box were dropped, and is counted from the left to the right when looking at the front of a stamp mill (or alternatively counted from the drive pulley end). The order was intended to create a wash within the mortar box that kept the crushed ore moving and avoided a build up at the ends. The most commonly found order in surviving New Zealand mills is 1,4,2,5,3 and its reciprocal 1,3,5,2,4 (Petchey 2013:225). This was the drop order that was historically considered to be the most common and is known to have been used widely in New Zealand, Africa and the United States of America (Gordon 1894:313, 1906:382; Louis 1902:209). It is the pattern defined by White (2010:69) as the 'Reverse Homestake' and the 'Homestake.'

Other orders are found in New Zealand mills, including 1,4,2,3,5 (known as the 'California' pattern (White 2010: 68)), and the unexpected use of orders in which pairs of stamps were dropped simultaneously; (1,5)3(2,4) or (1,5)(2,4)3. This latter practice runs counter to a number of contemporary sources (e.g. Gordon 1906:313), and was possibly done to increase the splash in the mortar box. It was recorded in seven surviving stamp mills, so was a deliberate and reasonably common strategy.

THE ARCHAEOLOGICAL ANALYSIS OF THE STAMP MILL

The engineering of any individual surviving stamp mill is the end result of a long series of human decisions and actions, from the design and manufacture of the component parts, through to the transport and manhandling of the parts, fitting and erection of the mill, maintenance and repair, modification and relocation, the decision to abandon the mill on site, and finally to subsequent events such as the scavenging and removal of various parts. An overarching consideration that affected many of these decisions was the success or failure of the gold mining venture(s) in question. Archaeological analysis of the engineering of the mill can provide information about many of these aspects of its life, over and above the historical detail that it is often possible to glean from official goldfields records such as the annual Mines Department reports in the *Appendices to the Journals of the House of Representatives*.

The 'archaeology of the machine' is an approach that uses the detailed and forensic methods of archaeology to study industrial sites and machinery (Bailey and Glithero 2000; Cossons 2007:16; Gordon and Malone 1994:24, 349). 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). One regular criticism of industrial archaeology 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 Raistrick (1973:12) clearly articulated his opinion that industrial archaeology 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'. Recent work in America by White (2010) has begun to apply this approach to the stamp mill, and he considered the pragmatic strategies employed at the Skidoo Mill in California to keep an ageing and increasingly worn out plant in operation.

THE UNITED GOLDFIELDS BATTERY, MACETOWN

To explore some of these interpretative approaches, the stamp mill at the United Goldfields Battery at Macetown is used here as an example (Figure 8). This ten stamp mill was erected beside Sylvia Creek sometime between 1910 and 1918, either by New Zealand Consolidated Gold Mines Ltd, or its successor United Goldfields Ltd, using parts from older mills. It was built to rework several local mines, and operated until about 1920, when it was abandoned on site (Petchey 2013:672; Veitch 1972). The calculated weight of the stamps (based on 2010 field measurements) is 820 lb (372 kg), placing it in the middle-weight range of New Zealand mills.

Unravelling the chronology

The historical information regarding a stamp mill that is usually most accessible is the basic detail about its last date of erection and use, and the company responsible. However, this is often only the last event in what was, in some instances, a very long working life. Mining equipment was frequently reused and recycled, either complete or recombined with other parts, and more often than not the date of manufacture and date of last erection are not the same.

Neville Ritchie (1990:9) has observed that there is often an inherent 'late bias' in the archaeology of mining sites, as the surviving features represent only the last stages of operation and often obscure earlier evidence, while Petchey (2013:157, 162) has identified a counter-acting 'early bias' whereby early machinery was often re-used at a later site, and was more likely to be abandoned on site than more up-to-date equipment. These two processes have produced an archaeological record that can be complex to interpret, but an analysis of the surviving machinery with a particular focus on design features that can be securely dated (often by using patent information) can help to clarify the operational history of the site, and identify situations where older machinery had been re-used.

In the case of the United Goldfields Battery, it is known from archival sources that the mill was erected in the 1910s, and the use of concrete foundations for the mortars is consistent with this date. However examination of the machinery clearly shows that it was built from parts of other mills, the most notable features being the mortar boxes, which are of quite different patterns. The right hand box is of the inclined slot screen type, and is embossed 'A&G Price, Makers, Thames, 1898.' It was therefore at least twelve years old when installed at this site. The left hand box is of the vertical bolt on screen type, and although the maker's plate is missing, it is a design typical of the 1870s and was potentially up to 40 years old when installed. This box also has a notably thinner base, and certainly weighs considerably less than the 1898 box, and was made for use with lighter stamps. The difference in base thickness affects the box heights, and the concrete foundations have been cast asymmetrically to accommodate this.

The cams are conventionally mounted using keys and some show moderate wear with pitted lifting faces. The drop order in both mortar boxes was 1,5,2,4,3, a pattern commonly used in the United States of America but not popular in New Zealand, the only other recorded example being the 1870s Young Australian Battery in the Carrick Range (Louis 1902:209; Gordon 1906:382; Petchey 2013; Truscott 1923: 152). The camshaft is $4\,^{3}/_{8}$ inches (111 mm) diameter, which is very light for the 820 lb (372 kg) stamp weight, and is more suitable for 650 lb (295 kg) stamps (Petchey 2013:104; Richards 1906). The tappets are the gib type that are typical of the 1890s onwards, and are embossed 'A&G Price Thames'. They therefore match the right hand mortar box in terms of both origin and period. They show slight wear to their lifting faces. Some of the stamps are still fitted with almost new shoes that are up to 10 inches (254 mm) long, in the upper range of recorded shoe length, suggesting an attempt to increase stamp weight.

The mill has a timber A-frame, which again is more typical of the 1870s than the 1910s. There is physical evidence that it too was recycled from elsewhere, as it has an in-service repair to one post (a new section has been let in using a scarf-joint) that is unlikely to have been required if the frame had been new in the 1910s. A berdan also survives at the site, evidence of the mercury amalgamation post-crushing gold saving process.

The United Goldfields Battery therefore incorporates engineering features that date variously from the 1870s to the 1890s, on foundations that are appropriate for its 1910s erection. It is most likely that it in part originated as an 1870s A-frame ten-stamp mill of the 600 to 700 lb weight range, at some other location. By the time it was erected beside Sylvia Creek only one mortar box, the above-ground frame (in deteriorating condition) and the camshaft of the original machine survived. One mortar box and all of the stamps were replaced with parts from at least one other mill, the frame was repaired and new concrete foundations were constructed. This was not simply an attempt to repair an old mill and keep it in operation, as there is clear evidence that the stamp weights had been considerably increased. While the foundations had been improved to accommodate this increase, the camshaft was overloaded. This process of rebuilding, replacement and partial upgrading leads us to the subject of the men who built it and the decisions that they made in its design and construction.

Studying the people

The selection and use of mining machinery depended on a number of factors, including: the capital available; the skill and knowledge of the people involved; the nature of the ore body; and, the availability of suitable (or cheap) equipment. Ultimately, the machine is the result of human choices and reactions to all of these variables. The same engineering features that are discussed above in terms of technology and chronology can also be considered in terms of agency, as they are the physical evidence of these past choices and actions.

As discussed above, the United Goldfields Battery was constructed from second hand parts from several machines, which was a common practice in the goldfields. The availability of cheap machinery from failed operations was tempting, and often outweighed more serious issues, such as the actual suitability of that machinery. In 1879 the purchase of a used machine by the Longwoods Reefing Company in Southland led the local Warden to comment; 'as in many other first enterprises, a mistake was made in buying what was supposed to be a cheap machine from the Coromandel, which has proved to be very dear to the shareholders' (Appendices to the Journals of The House of Representatives 1880 H26:31). This machine (Printz's Battery) survives in the Longwood Range, too remote and outdated to have attracted the attention of later companies in need of a mill.

The erection of a stamp mill was not conceptually difficult, it was after all in essence a simple machine, but it did nevertheless require skill, care and knowledge. Several authors published detailed instructions about how to erect and adjust the machines (e.g. Louis 1902), but skilled millwrights or engineers were often employed to oversee construction (e.g. see Ulrich 1875:83). It was vital that all of the camshaft bearings were in line, the clearance between the camshaft and the stamp stems was correct and the mounting for the mortar boxes was secure. And as anyone with modern experience in constructing or restoring anything (from cars to furniture to houses) knows, putting together a disparate and modified set of parts is far more difficult than simply assembling a set of matched parts.

The mismatched United Goldfields Battery would therefore have required some skill to set it up to run properly. This is best seen in the different mortar block heights needed to suit the different mortar boxes. The construction of the blocks would have involved measuring both boxes (with dies in place), determining the correct die height relative to the rest of the mill, and then boxing and casting the concrete mortar blocks accordingly. The re-erection of the second hand A-frame involved not only the skill to set it up straight and level, but also the construction skills to repair a defective post. This repair involved carpentry skills to cut two scarf joints (one in the damaged post, one in the repair section) and then blacksmithing skills to make a new wrought iron strap for the post (this long strap is visible on the bottom of the right hand

Figure 8: The United Goldfields Battery beside Sylvia Creek near Macetown.

battery post in Figure 8). The decision was made to spend time repairing the existing post rather than simply replacing it, which suggests either that suitable timber was not available for a replacement, or that the cost of labour for the repair was cheaper than the cost of a new post.

More significant, but less immediately obvious, was the decision of the builders to increase the stamp weight, well above the recommended capacity of the camshaft and cams, and possibly the frame. Not only were heavy stamps fitted, but the last shoes to be used were also very large. The 820 lb stamps represent a 26 per cent static overload on the camshaft, which would have been exacerbated by the shock loading of the operating machine. This appears to have been a calculated risk on the part of the builders, as the foundations were strengthened suitably, but the mill would have been running overloaded with the risk of breakages and damage at any time, and its potential working life would have been considerably shortened. The mill was therefore clearly not erected with a long life in mind, but to produce the maximum crushing power from the available machinery for a limited time. This in turn indicates that it was intended to test a reef more thoroughly than a small prospecting mill could do, but was not intended to be a long-term installation. That the machine was abandoned without any evidence of major failure suggests that the reef proved to be uneconomic to work.

The decision to abandon the intact machinery was almost certainly an economic one; the ore body had proved uneconomic, and the failure of the other Macetown mines meant there was no longer any local demand for second-hand machinery. The larger and more expensive Homeward Bound Battery, situated only one kilometre away, was erected in 1910 and abandoned in about 1914, further proof of the victory of harsh economics over human optimism.

CONCLUSIONS

This paper set out with two main aims: to outline an historically correct terminology for the archaeological description of the New Zealand stamp mill, and to demonstrate how an 'archaeology of engineering' analysis can be used to examine various aspects of the stamp mill including its history and some of the decisions and actions of the people involved. Industrial archaeology has been criticised for its focus on buildings and machines and its lack of consideration of the human element. However, in the goldfields the stamp mill was a machine in which every part was designed, made, assembled and repaired by human hand. Analysis of the engineering of the machine can be used to consider the technology and chronology of the mill as well as the decisions and actions of the mill engineers, managers and workers.

The stamp mill at the United Goldfields Battery at Macetown exhibits a range of technological traits typical of the 1870s (A-frame, vertical bolt-on screen mortar box, lightweight camshaft), 1890s (inclined slot screen mortar box, gib tappets) and 1900s (concrete mortar block). This mixture not only confirms that it is an example of the common goldfields practice of reusing old equipment, but also allows us to consider the decisions and actions made at the time it was constructed. The evidence of repair work adds further detail to the picture that can be built up of men constructing a machine in a remote mountain valley using a mixture of parts, some reasonably new and some old and outdated. It was clearly a machine built to a budget, using some very old parts, and the stamp weight was increased as far as was reasonably practical to the point where the machine was overloaded. This suggests that it was built to test a promising gold reef, but was not seen by its builders as a permanent solution should the mine prove profitable. Nevertheless, there is ample evidence of the application of engineering and carpentry skills that were employed in the construction of the mill.

The mill was a pragmatic response to a series of constraints and requirements that were not uncommon in the remote mountainous goldfields. Its survival allows us to consider the decisions made a century ago to address these issues. As White (2010:66) has observed, an archaeological approach to the stamp mill allows a 'perspective from the shop floor' that is not possible through documentary records, and an analysis of the United Goldfields Battery shows how a whole series of pragmatic human decisions created what the official records would simply regard as a ten stamp mill.

This is only a very basic introduction to the analysis of the stamp mill from an archaeological perspective, but it illustrates the potential for this type of detailed engineering approach. In the same way that prehistoric archaeologists can examine lithics for evidence of manufacturing technology, usewear and retouch, so the industrial archaeologist can examine the machine for the same traits, and can produce comparable results.

ACKNOWLEDGEMENTS

The preparation of this paper was funded by a University of Otago writing bursary. It is based in my PhD research in the Department of Anthropology and Archaeology. Many people have assisted with this research, and I can not name them all here. I am particularly grateful to Neville Ritchie, Rachael Egerton and Jim Station, all of the Department of Conservation, for many conversations and insights into gold mining archaeology and history. I would also like to thank my two anonymous referees for their comments on the paper.

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