

## 2.0 Background – limeburning

### 2.1 Geology

Limestone is a common sedimentary rock formed in both marine and non-marine environments. It makes up about 20 per cent of all sedimentary rocks and is found with other types of sedimentary rock, such as shale, sandstone and clay. It is commonly composed of  $\text{CaCO}_3$  (calcite, aragonite) and  $\text{MgCO}_3 \cdot \text{CaCO}_3$  (dolomite) and will often contain  $\text{FeCO}_3$  (siderite),  $\text{Ca}_2\text{MgFe}(\text{CO}_3)_4$  (anarite) and  $\text{MgCO}_3$  (magnesite). The term 'limestone' is used only for sedimentary rocks in which the carbonate fraction exceeds the non-carbonate constituents. In terms of lime manufacture, limestone is the general term used for the class of rocks that contain at least 80 per cent of carbonate of calcium or magnesium. By definition, 'high-quality' limestone contains 97–99 per cent calcium carbonate, and impure limestone contains less than 90 per cent carbonate minerals.<sup>1</sup>

### 2.2 Chemistry

Limeburning is an ancient practice. On face value, it is a simple process in which a practitioner heats the raw material, either in a simple pit or in a kiln. It does, however, require a certain level of knowledge and skill to be most effective.

Lime does not occur in a free state in nature. It can be obtained by the application of heat to a calcium-rich substance, such as limestone, chalk, coral or seashell, which promotes a process known as calcination. For this to occur, the raw material must be heated to a temperature between 812<sup>o</sup> and 1100<sup>o</sup> Celsius. The chemical cycle is summarised in Figs 1 and 2.

When limestone (calcium carbonate –  $\text{CaCO}_3$ ) is burned, the end products are carbon dioxide ( $\text{CO}_2$ ) and calcium oxide (CO). This reaction is also called calcination. The calcium oxide remains

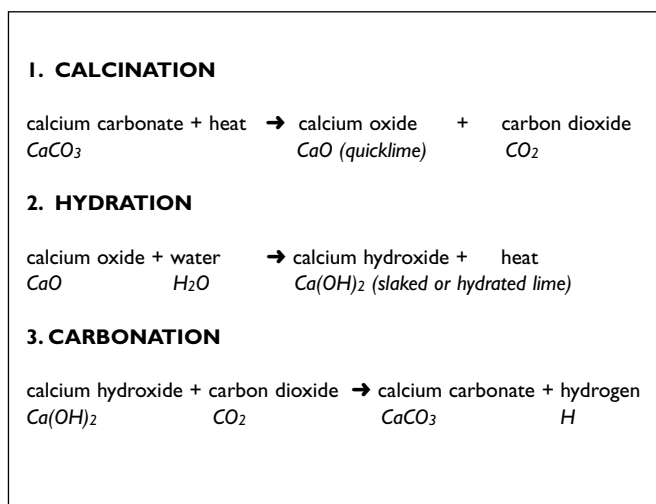


Fig. 1. Chemistry of lime

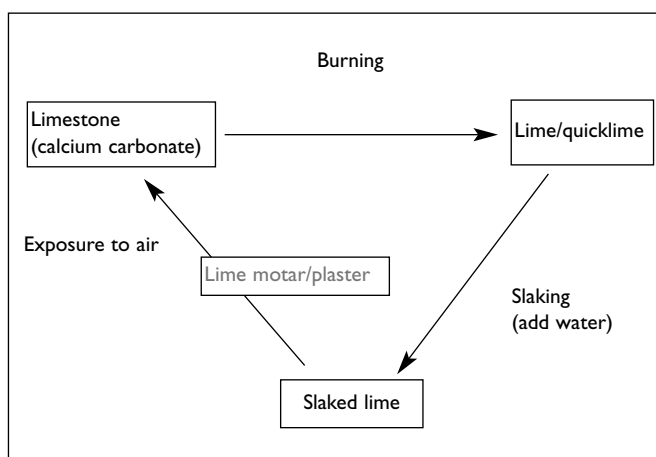


Fig. 2. Lime cycle

in a lump or powdery form that is otherwise known as lime, roach lime or quicklime.<sup>2</sup> The resulting product is generally white, but can be various other shades depending on the presence of impurities and the standard of the burning process. Few limestones come in a form that is pure calcium carbonate as many contain clay impurities.

Quicklime requires careful handling as it can react vigorously with water to become calcium hydroxide [ $\text{Ca}(\text{OH})_2$ ] or hydrated lime, a process

<sup>1</sup> Inan et al. 1992, p. 104.

<sup>2</sup> Wingate 1985, p. 114. The English word 'quick' used to mean 'alive'. As quicklime can react so vigorously with water it was thought to have life in it.

known as ‘slaking’. The lime absorbs the water and gives off heat up to 300<sup>0</sup> Celsius, causing rapid expansion.<sup>3</sup> If the lime is pure and burned correctly, the lumps will fall to a dry powder when water is added. The addition of further water will cause the hydrate to convert to putty that is a soft, smooth material, which can be stored indefinitely if it is kept wet. The hydrated lime is then mixed with sand to make mortar. On drying, the substance effectively reverts to calcium oxide, and absorbs carbon dioxide from the atmosphere to be reconstituted as calcium carbonate.

Although the process appears elementary, and is chemically a fairly basic reaction, limeburning is attended by a degree of complexity that requires some skill on the part of the practitioner:

In spite of incontrovertible scientific data delineating calcination, this process still remains to some extent a technique or an art that only an experienced lime burner fully comprehends... formally trained engineers are simply no match, at least at the outset, for the veteran lime burner...the latter is like a ‘French’ chef; the former is a novice cook.<sup>4</sup>

## 2.3 The uses of lime

Lime is used extensively and has a wide range of application other than in construction. Its chemical and physical properties, together with the low cost of its production, make it a desirable ingredient in many industrial processes including steel manufacture, sugar production, leather tanning, glass manufacture, large-scale paper-making, sewage treatment, and the preparation of certain bleaches and dyes. Most metal extraction industries use lime in their processing; for example, it is used to neutralise acidic gases released in the smelting of copper, zinc and lead.

Lime was once used in agriculture to neutralise soil, but now crushed chalk or limestone is commonly applied to achieve a similar but more economical result. Lime is still used in market gardens to adjust soil acidity and to assist the action of fertilisers.

Lime is often used on farms to destroy the carcasses of dead animals. The historical use of lime to hasten the decomposition of human corpses is also recorded. The practice of painting walls with whitewash, while certainly a cheap form of paint, also had the added advantage of acting as a mild germicide.

## 2.4 Early history and use

Lime and limestone are among the oldest building materials. It is believed that lime was discovered during the Neolithic period when it was observed that slabs of limestone used around fireplaces disintegrated into a white, paste-like substance after heavy rain: the limestone having been calcined by the heat and converted to quicklime on hydration.

Many ancient civilisations, including the Incas and Mayas, appear to have independently discovered lime and perfected their own uses for it. Archaeological evidence has revealed such creative applications as slaking quicklime in barley water and mixing the lime with animal blood.<sup>5</sup> Small fragments of burned and partially burned lime excavated at a site in northern Peru were found with hearth material that has radiocarbon dates ranging from 5300 to 4800 BC. Ethnographic analogy suggests that the lime might have been used either as a mineral supplement with certain foods or as an extractive agent with coca. The excavators propose that the process of limeburning contributed to the development of complex social structures: ‘public activity and the development of a ritually sanctioned extraction technology was an instrument for consolidating social and cultural identity’.<sup>6</sup>

More than 3000 years ago, the Cretan civilisation utilised lime as a masonry mortar; the use of lime for mortar and plaster in China is of a similar antiquity. By Roman times, lime had become one of the basic building materials. Vitruvius devotes an entire chapter of his *Ten Books on Architecture* to lime and promotes it as the proper mortar material for structural walls and ornamental plaster. The burning of

<sup>3</sup> Ibid., p. 5; Lindsay 1975, p. 15.

<sup>4</sup> Boynton 1966, p. 132.

<sup>5</sup> Ibid., p. 3.

<sup>6</sup> Dillehay et al. 1997, pp. 46-55.

lime in kilns is given its first written reference by Cato in 184 BC.<sup>7</sup>

Although the original use of lime appears to be structural, both the Greeks and Romans used it as a chemical reagent. In 350 BC, Xenophon recorded that a ship carrying linen and lime was wrecked near Marseilles: the coincidence of the two materials is not surprising as lime was commonly used to bleach linen. The Roman Dioscorides, writing in AD 75, recorded that medical benefits were attained by the use of saturated solutions of limewater. The English are reported to have thrown quicklime in the faces of the French during a war in 1217, perhaps the first recorded use of chemical warfare. European alchemists in the Middle Ages are known to have utilised lime in the production of a crude form of lye, used as a base for soapmaking.<sup>8</sup>

The use of lime as a fertiliser has a similarly long history. In Britain, by the last quarter of the 18th century, spreading lime on land had become a common practice, even on quite small farms. The annual application of prescribed quantities of lime had even become a condition on many leases in that period, leading to an increased demand for burned lime.<sup>9</sup>

## 2.5 Britain and the development of cement

The knowledge of lime and its uses appears to have been introduced to Britain by the Romans in the 1st century AD. (About 17 Romano-British limekiln sites are presently known in England.) After the departure of the Romans, the major recorded use of lime before the mid-18th century is found in references to plaster and stucco applications during the 16th and 17th centuries.<sup>10</sup> However, the predominance of limekiln and limeburning sites from various periods throughout Britain, particularly in rural areas, suggests that limeburning was a

common but unattested practice in many places. The provision of lime for a range of purposes was no doubt deemed a mundane activity, warranting very little mention in the historical record.

The first recorded use of hydraulic lime is dated to 1759 when John Smeaton, a Leeds engineer, was engaged in the construction of the third Eddystone lighthouse and found that he needed to have a cement that was capable of rapid hardening under water (pure lime is non-hydraulic – it won't set under water).<sup>11</sup> Smeaton discovered that limes set more effectively under water if they had sufficient clay content in them when burned (in excess of 5 per cent).<sup>12</sup> As a result the composition of plaster for wall-finishing, of mortar for joining stone or brickwork, and of concrete for foundations all underwent important developments.

Natural cement can be produced when the clay content exceeds 12 per cent. In 1796, the use of natural cement was patented under the name of Roman cement, an allusion to the durability of the structures surviving from the Roman occupation of Britain. The patent was originally granted to the Rev. Dr James Parker, for a term of 14 years. Parker used nodules of septaria (clayey limestone), heating them to a greater temperature than that used for lime.<sup>13</sup> His cement had superior water-resistant properties: Brunel employed it, for example, for the construction of the Thames Tunnel.<sup>14</sup>

In 1824 Joseph Aspdin, a bricklayer turned builder, was granted the patent for a particularly strong material called Portland cement.<sup>15</sup> Aspdin had stumbled onto a process whereby a mixture of chalk and clay could be calcined at a temperature high enough to cause the particles to coalesce without actually melting, creating a product which was superior in strength and consistency. The firing was undertaken in a type of bottle kiln, quite dissimilar to traditional limekilns. Roman cement, therefore, is a natural combination of materials, while Portland cement is a form of artificial cement obtained by mixing

<sup>7</sup> Wingate 1985.

<sup>8</sup> Ibid.

<sup>9</sup> Cleasby 1995, p. 19.

<sup>10</sup> Nelms 1985, p. 6.

<sup>11</sup> Derry & Williams 1979, p. 405. It wasn't until 1839 that the theory of mixing lime and clay to form cement was actually stated. It was attributed to the Frenchman L.J. Vicat who made a successful cement for Cherbourg Harbour. Vicat is first recorded as using the word 'hydraulic' for the essential quality of hardening and becoming impervious under water.

<sup>12</sup> Sheppard 1981, p. 3.

<sup>13</sup> Ibid.

<sup>14</sup> Cossons 1993, p. 159.

<sup>15</sup> Called 'Portland' cement because it resembled the colour of Portland stone.

separate materials in desired proportions. Improvements in the production of Portland cement led to its increased use, its level of competitiveness being restricted by the expense of producing it in non-continuous bottle kilns (see section 3.3 below). A continuous process rotary kiln was designed in the 1880s, which led to the large-scale use of Portland cement and the replacement of lime mortar as the predominant construction material.<sup>16</sup>

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<sup>16</sup> Derry & Williams 1979, pp. 405-406; Sheppard 1981, p. 4.

## 3.0 Limeburning methodologies and kiln types

Limeburning methodologies vary from burning a small pile of limestone or shell on the ground-surface to the construction of large groups of kilns. Different communities in different parts of the world have developed their own styles and methods of limeburning, as well as uses of lime. The limeburning processes below are a generalised discussion of traditional methods used in Britain (they were similar in Europe) and which had practical application in colonial Australia. Major technological advances in limeburning have taken place this century; however, a discussion of these is outside of the scope of this report. In a practical sense, very little has changed today on two levels: first, in many parts of the world traditional practices are still used (Fig. 3); and second, although the technology applied in burning processes has advanced dramatically, the basic chemistry of the process remains unchanged.



Fig. 3. Limekilns in Gujarat, India (Jane Harrington)

### 3.1 Heap burning

The simplest method of limeburning involves the construction of a heap or pile of alternating layers of limestone and wood, which is set alight and allowed to burn out. This process requires equal amounts of fuel to stone and results in an end product that has a high percentage of contaminated and unusable material. Although it is simple and cheap, the lack of control in its operation means it is not a particularly efficient process.

### 3.2 Pit burning

Pit burning is an advanced form of heap burning and involves the excavation of simple ground pits (Fig. 5 'A'). A study of small-scale limeburning practices in use today notes that pits

are typically rectangular (around 2.75 metres by 2.5 metres) and 1.5 metres to 2.0 metres deep. A trench is sometimes added to the pit to provide a draft for the fire. The trench is often reinforced at the edge nearest the exit point by flanking stones; an additional stone can be inserted between the flanks to act as a door between the pit and the trench.<sup>17</sup> As with simple heap burning methods, the lime and wood are layered, the layers often extending above the pit perimeter to form a mound. In some cases, the heap may be covered with an insulating layer of sods. Once lit, the fire may burn for 24 hours or more, during which time the material settles into the pit where the heat is retained for several days. The cooled lime is then picked over to separate the unburned and overburned stone from the good quicklime.<sup>18</sup>

The historical use of an extended version of the simple pit excavation is illustrated in the construction of pye (or clamp) kilns, found in Britain. These are shallow, stone-lined,

<sup>17</sup> Wingate 1985, p. 72.

<sup>18</sup> Ibid., p. 72–73.



Fig. 4. Dibley's Kilns at Coimadai originally operated as flare kilns (Jane Harrington)

longitudinal pits (some in excess of 20 metres long), sometimes cut into a rise on three sides with a stone wall forming the fourth. Channels were excavated in the bottom of the pit, which ran into openings (usually two or three) or 'doorways' that allowed air-flow. The pit was lined with a layer of dry wood, then alternating layers of coal and limestone. The resulting stack could reach up to two metres in height and be topped with a layer of sod.<sup>19</sup>

The advantage of pye kilns over shaft kilns (see below) was the simplicity of construction. Pye kilns were more expedient if the need was temporary, and more efficient in terms of fuel consumption per volume of lime produced.

### 3.3 Masonry kilns

It is interesting to note that most of the advances in kiln design and technology have occurred since 1900, and that prior to this there was little difference between 19th century kilns and those used in antiquity.<sup>20</sup> Kilns are generally defined by a combination of two characteristics, the first being the burning process used in the kiln, the second the type or style of kiln structure. There is a degree of overlap and there are problems with assigning a specific burning process to certain structural types. However, these categorisations are commonly used and do allow for a general and useful differentiation between kiln types.

#### 3.3.1. Burning processes

Kilns can be divided into two categories, INTERMITTENT kilns or CONTINUOUS (RUNNING) kilns, on the basis of the continuity of the load being burned.

##### Intermittent kilns

In this type of burning process the limestone is burned in single and discrete batches and the burned product is totally removed prior to adding a fresh charge. The kiln is loaded with fuel and limestone and set alight with the intention of burning that particular load to completion. The lime produced is subsequently removed and a second discrete load is added for the process to begin again. The two most common types of intermittent kilns are known as the flare kiln and the mixed-feed kiln.

##### Flare kilns

Flare kilns are sometimes equated with pot kilns, although some references define pot kilns as a subset or type of flare kiln. The shape, material and size of these kilns are all variable but the feature they share in common is that the limestone and the fuel are kept separate. Limestone is placed inside a kiln, over one or more grates on which the fuel is burned. The grates, which may not be present in all instances, are often laid over a shallow pit that acts as an ash box. Usually the limeburner would place an initial charge of fuel on the grate and construct a rough dome of large stones over the top. As the larger stones are closer to the fire this facilitates an easier and more complete calcination through to their core. They are topped by progressively smaller stones, with the objective of creating a network of voids through which the flames can travel to ensure an even heating of the kiln.

The fire is lit and refuelled until the limeburner judges that all the limestone has been converted to lime, which can be up to 72 hours after lighting. According to Diderot's 1753 *Encyclopédie*:

One knows that the lime is burned when the top of the kiln does not give off any more smoke, when the load of lime settles about once-sixth of its total height, and when the centre of the mass of stone is a nice bright red and whitish pink.<sup>21</sup>

<sup>19</sup> Leach 1995.

<sup>20</sup> Boynton 1966, p. 204.

<sup>21</sup> In Lindsay 1975, p. 11.

The kiln is allowed to cool down until the burned material can be handled. The ash is removed from the pit underneath the grate, and the lime is withdrawn through the draw hole. Although the advantage of a flare kiln is that the lime and fuel are kept separate – potentially resulting in a purer product than if the lime and fuel are mixed (see below) – the process is relatively inefficient as the end result usually contains about 25 per cent overburned lime and the same amount of underburned lime. Additionally, heat losses are great as the kiln cools down during each discharge.<sup>22</sup>

As with other kiln types, flare kilns can be freestanding but are often built into the side of a hill or reinforced with earth.

There are only two examples in Victoria that are known to have operated as flare kilns – Dibley's Kilns (H7722-0001) (Fig. 4) and the lesser kiln at the Fossil Beach Cement Works (H7921-0021).

### Vertical mixed-feed kilns

Mixed-feed kilns are most often constructed as hillside kilns (see below) with a cylindrical shaft, containing a draw hole at the base, but without a grate. A layer of fuel is placed at the base of the shaft, and the shaft is filled from the top with alternate layers of limestone and fuel. One description of the process records that the bottom layer consists of 3–4 feet of brush and kindling, then 12 inches of heavier wood, followed by 18-inch layers of limestone and 12-inch layers of wood.<sup>23</sup> The load is then lit from the bottom and allowed to burn through without the need of further attention. When the material has cooled down, the lime is removed through the draw hole.

The method uses more fuel than a flare kiln but does not require the same level of skill in the limeburner. The product also has the disadvantage of often being contaminated with ash and containing a higher proportion of underburned and overburned lime. (Inefficiencies and expense aside, it is notable that this type of kiln operation was regularly and commonly applied in the Australian context – see section 6.0 'Discussion'.) With the exception of the two

known flare kilns (see above), it is likely that the majority of the kilns located in this study were operated as vertical mixed-feed kilns. Although the larger, commercial kilns were probably run on a continuous basis (see 'Continuous kilns' below) they could also be run intermittently. This means that the method of operation – intermittent versus continuous – cannot necessarily be determined on the basis of the structural remains.

### Continuous kilns

Continuous kilns are also known as RUNNING or DRAW kilns. The limeburning process is not punctuated by periods of cooling down and unloading, but is continuous with both fuel and limestone being added to the top of the kiln as the burned product is removed from the draw hole at the bottom. It should be noted, however, that while the burn is continuous, the drawing process itself can be staggered.

Seen as a major improvement on both of the above intermittent kilns, running kilns can be similar in design to intermittent mixed-feed kilns and are charged in much the same way with alternating layers of limestone and fuel. They are also commonly built into hillsides. After a period of burning, the limeburner judges when the stone closest to the bottom has been converted to lime and starts to draw out some of the material through one or more openings around the base. The level of the material in the kiln is maintained by the addition of further layers of limestone and fuel at the top of the shaft. In this way, the burn can be continued for indefinite periods.

The limeburning skills involved in efficiently operating a draw kiln are generally greater than those necessary to run an intermittent mixed-feed kiln. The operator is required to maintain a range of temperatures within the kiln and prevent the major heat zone (the zone of dissociation or calcination) from rising too high in the kiln: this runs the risk that the fire may break through at the top layers and reduce the efficiency of the process. The theoretical ideal is to maintain bands that allow space for four separate activities: storage and drying, preheating, calcining and cooling. When the

<sup>22</sup> Boynton 1966, pp. 204–205.

<sup>23</sup> Hollinshead 1982, p. 50.

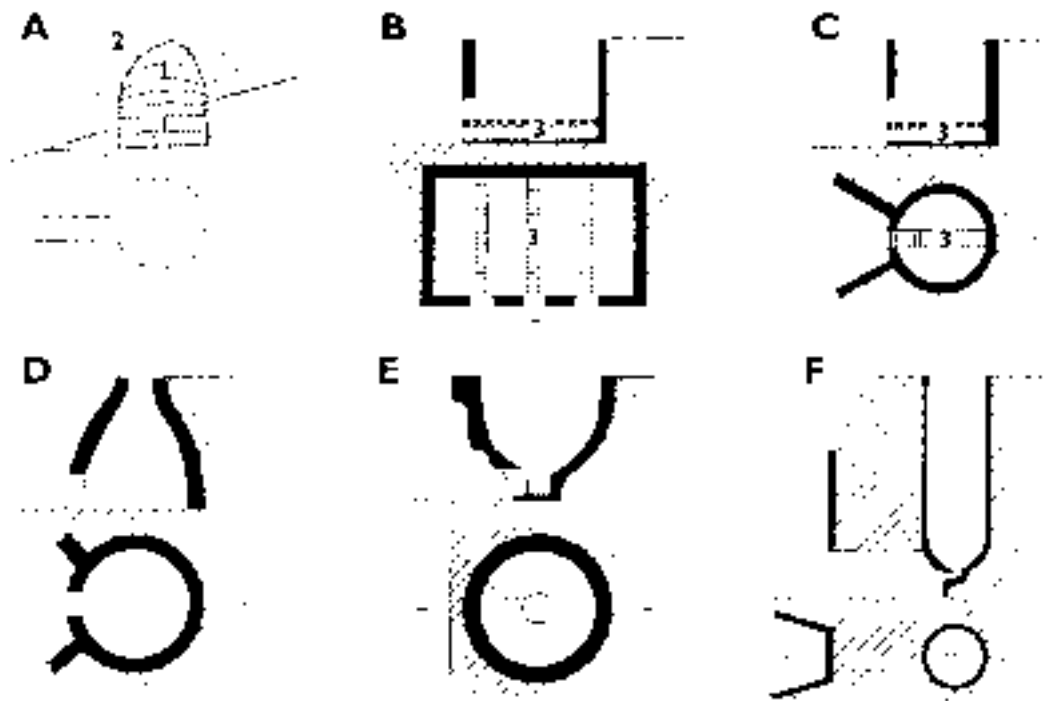


Fig. 5. Schematic outline of various kiln types, showing plan and cross-sectional elevation of each major type (not to scale).

**A.** Pit-burn kiln; **B.** 'D' kiln; **C.** Small cylindrical shaft kiln; **D.** Inverted cone (bottle) kiln; **E.** Inverted bell kiln; **F.** Continuous feed shaft kiln.  
**1.** Limestone or shell; **2.** Fuel (wood or coal); **3.** Ash pit.  
 (From Pearson 1990, p. 29. Reproduced with permission.)

lime is drawn from the bottom the bands will drop down.<sup>24</sup> Consequently, there is a relationship between the efficiency of the process, the height of the shaft and the diameter of the shaft opening. As a general rule, draw kilns require a greater shaft depth than either type of intermittent kiln. In order to promote an effective downward movement of the lime, there is an advantage in fashioning the lower part of the kiln into a funnel (or 'inverted bottle') shape (Fig. 5 'F'). When attempting to characterise a particular kiln, although the presence of a deeper shaft with a funnel suggests a continuous burning operation, it should not be assumed: first, that this was always the burning method applied; or second, that slightly shorter kilns or kilns without a funnel were not sometimes burnt continuously as well as intermittently.

### 3.3.2. Structure and construction types

In the most general sense, kilns can be constructed either into a hillside or as a free-

standing structure. Burning is most effective when the shaft is well insulated, the top of the kiln can be accessed and loaded with ease, and the lime can be extracted with similar lack of complication from the base of the shaft. The easiest way to achieve this is to construct a kiln directly into a hillside. This method of construction is recommended, for example, in references such as *Tomlinsons Cyclopaedia* 1852–53:

The best situation for this [Mr Louden's lime kiln], or indeed for most other forms of kiln, is the face of a steep bank; but if this cannot be obtained, it may be constructed on a level surface with a ramped road or incline, or with a mechanical lift for conveying the materials to the top of the kiln.<sup>25</sup>

The cost in terms of both energy and expense made the additional construction of a separate ramp less attractive, but this was compounded dramatically by the structural additions required to meet the insulation needs of a freestanding kiln. It is, therefore, no surprise to find that the vast majority of limekilns in the Australian

<sup>24</sup> Wingate 1985, p. 98.

<sup>25</sup> *Tomlinson's Cyclopaedia*, 1852–53, p. 297, in McCarthy and Varman 1982.

context are constructed into hillsides or equivalent landscape features.

Michael Pearson has already provided a basic structural typology in a 1990 paper published in the *Australian Journal of Historical Archaeology*: 'The Lime Industry in Australia – An Overview'.<sup>26</sup> His description of kiln types is comprehensive and I prefer to follow this as a guideline for this study. The schematic outline of kiln types has been reproduced as Fig. 5.

The main kiln types relevant to the history of limeburning in Australia are defined as:

- bell-shaped kilns (inverted or truncated cone): commonly flare or intermittent mixed-feed kilns
- 'D'-shaped kilns: commonly flare or intermittent mixed-feed kilns
- cylindrical (short) shaft kilns: commonly flare or intermittent mixed-feed kilns
- vertical (deep) shaft or bottle kilns: commonly continuous kilns
- Hoffman kilns: continuous kilns.

### Bell-shaped kilns

These kilns are usually built into the side of a hill or slope. 'Inverted' bell-shaped kilns have a relatively large diameter (sometimes > 5.0 metres) at the top of the shaft, and the shaft curves inward at the bottom to create a neck or funnel. 'Truncated cone' kilns are the same shape turned on end; that is, the narrower neck area is at the top of the shaft. They are usually brick-lined. This shape allows effective utilisation of irregular landscape features such as sinkholes and semi-established natural pits (Fig. 5 'D' and 'E').

An outstanding and rare example of this type is located in western Victoria (Bat's Ridge Kilns – H7121-0002).

### 'D'-shaped kilns

These are the commonest types of kiln found in New South Wales dating to the late 19th and early 20th centuries (Fig. 5 'B'); however, no examples are known in Victoria. A 'D'-shaped

kiln consists of an excavation into a hill or slope, with a masonry wall constructed across the front: this creates the characteristic 'D' shape. The base of the kiln is divided into two or three ash boxes, either covered with brick or iron fire bars. Each ash box has an opening through the front wall, with an arched draw hole over the top. The kiln dimensions are typically: length (across front) 4.3–6.7 metres; height 2.4–4.3 metres; and depth 3.0–4.9 metres.<sup>27</sup>

### Cylindrical (short) shaft kilns

The shaft of this type of kiln is usually cylindrical (Fig. 'C'). Square varieties have been recorded elsewhere, but not in Victoria. They usually operate in a similar manner to D-shaped kilns but are smaller, being only 2–4 metres in diameter (or square) and 2–3 metres deep. The sides of the shaft are vertical and there is a single ash box and draw hole at the base of the kiln. They can function as either a flare or mixed-feed kiln.<sup>28</sup>

These types of kilns are not well represented in Victoria – a typical example is the three-kiln complex found at the Blair's Road site in Lara (Blair's Road Limekilns – H7721-0063; see Fig. 21).

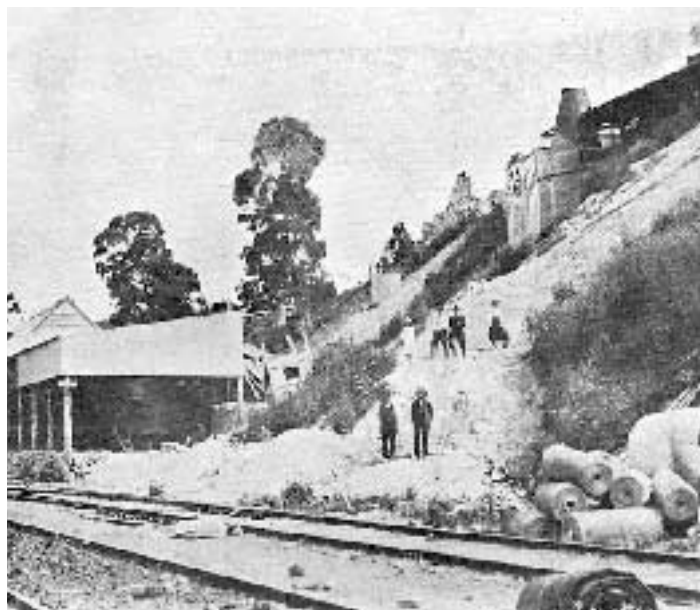


Fig. 6. 'John Bull' Limekiln, Curdie's River 1913. *News of the Week*, 27 February 1913, p.15 (Geelong Historical Records Centre)

<sup>26</sup> Pearson 1990.

<sup>27</sup> *Ibid.*, p. 30.

<sup>28</sup> *Ibid.*, p. 31.



Fig. 7. Shaft kiln at Limeburner's Point, Geelong, showing front retaining wall, remnant wing walls and top of vault (Heritage Victoria)



Fig. 8. Outstanding examples of Hoffman kilns survive at the former Hoffman Brickworks, Brunswick (Heritage Victoria)

### Vertical (deep) shaft or bottle kilns

Shaft kilns are commonly built as hillside kilns, constructed against an escarpment or into a slope to provide stability, insulation and easy access to the top for loading (Fig. 5 'F'). A hillside kiln generally comprises a shaft (or chimney), a front retaining wall (sometimes reinforced by metal bands), a tunnel or vault which gives access to a draw hole, a front working area and a pair of flanking wing walls. The shaft is between 7–9 metres deep and usually narrows towards the base, sometimes terminating in a narrow funnel (bottleneck) allowing for an easy, downward movement of the load. Some shafts have holes at a suitable height to assist with checking and moving the load. A form of roof, supported by cross beams and the retaining walls, often covers the working area at the front of the kiln. This roofed area is usually enclosed with a front wall and large access doors, to provide a sheltered area. Historical photographs show that some kilns had a small structure constructed over the top of the shaft itself (Fig. 6 Curdie's River kiln, 1913). The remaining kilns at Limeburner's Point are typical examples of shaft kilns (Limeburner's Point Limekilns – H7721-0003; H 1288 Fig. 7)

### Hoffman kilns

For completeness, Hoffman Kilns should be mentioned, although it appears that no lime-

kilns are known in Australia that have been constructed in this form.<sup>29</sup> Hoffman patented a circular kiln in 1858, followed in 1870 by a rectangular form, both of which were originally designed for the manufacture of bricks, but which have been constructed to burn lime. The kiln tunnel is effectively divided into chambers which are subject to a series of activities, rotating around the kiln to maintain a continuous burn: packing, firing and pre-heating, and cooling and drawing. A proportion of the chambers at any time will be left empty. Packing involves the building up of limestone to ceiling height in stacks that run the width of the tunnel; on completion, the entrance to the chamber is blocked. The fire is advanced through the various chambers through the operation of a system of flue dampers.<sup>30</sup>

One of the advantages of operating a Hoffman kiln was that the movement of burning zones allowed maintenance work to be carried out while the kiln remained operational. Another, according to a 1900 manual, is that when the locality is favourable, it is possible to use the kiln to burn both lime and bricks at the same time.<sup>31</sup>

Although there are no known examples in Australia of a Hoffman kiln being used to burn lime, some outstanding examples of Hoffman kilns are found at the Hoffman Brick Works in Brunswick (H7822-0019; H 703; Fig. 8) and at the former Standard Brickworks, Box Hill (H 720).

<sup>29</sup> Serle (1935) includes this in his lime kiln typology (in Trueman 1992, p. 134); Trueman (1992) also indicates that there are at least two examples recorded in Britain.

<sup>30</sup> Trueman 1992.

<sup>31</sup> Crooks 1900, p. 667.