Rockwork features

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Rockwork features in British gardens 1710-1911: how were they built?

It is as foolish to expect a nurseryman, untrained in design, to build you a harmonious, genuine, schemed rock-garden, as to ask a journeyman mason to make you a palace. The builder of a rockery must be, on his own different lines, as much of an architect as any planner of houses.

Reginal Farrer, 1908.

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Chapter 1
Introduction

This research aims to identify the construction techniques used to create different types of rockwork and their attendant water features found in eighteenth century (18C) and nineteenth century (19C) British gardens. The scope includes grottoes, cascades, re-creations of natural landscapes and rock gardens for growing alpine plants. Both real and artificial rock will be considered.

Much has been written about the history, aesthetics and iconography of rockwork in gardens, but very little research has focused on how they were built – where the rock came from, how it was transported, moved and handled, how rocks were held in position, what tools and machines were used and what skills were learnt or imported from other industries. Many rockwork features were accompanied by water, often in the form of a cascade. Hence the area of water management is also an important element in this research.

Roberts, writing about constructing water features in the 18C landscape park notes that 'little consideration has been given to the process of making the landscape' while Wass contends that 'our understanding of the technology employed in period gardens remains limited'.[1] A recent Dumbarton Oaks Symposium also acknowledges the lack of research in this area.[2] Only recently has any research focussed on technology within country houses and their estates, fuelled by an interest in restoration of equipment and services for display to visitors. Aspects of The Country House Technology project pertinent to this dissertation are the areas of transport and energy

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[1] Judith Roberts, 'Well-tempered clay: constructing water features in the landscape park', *Garden History*, 29.1 (2000), pp. 12-28; Stephen Wass, 'A way with water: water resources in the life of an 18th century park' (unpublished MA thesis, University of Leicester, 2012), p. 36.

[2] Michael G. Lee and Kenneth I. Helphand (eds.), *Technology and the garden* (Washington, 2014), pp. 1-6.

provision.[3] The primary objective of this dissertation is to fill some of the gaps identified above.

The key questions posed are:

1. What materials, methods and equipment were used in constructing the rockwork features?
2. Did the construction stages follow those used in building a house?
3. From where did rockwork builders obtain the necessary knowledge and skills?

Sources of information

Direct sources such as original plans, diaries and estate papers were the first choice. However, expert advice suggested that information about construction methods would be hard to find and for this reason a range of indirect sources have also been considered.[4]

Visiting gardens became popular in the 18C and many visitors wrote about their experiences. According to Batey and Lambert 'garden tourists have a long and distinguished pedigree' and often described the new styles they saw.[5] For this research records from visitors were analysed alongside other indirect sources including contemporary drawings and paintings, contractor brochures and advertisements and more recent accounts and commentary from garden historians. Recent restoration projects are included as they often involve archaeological surveys and the dismantling of existing structures revealing what was underneath and have the potential to identify construction details. Finally, collections of early 19C

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[3] The Country House Technology project at the University of Leicester led to a conference in May 2010 and several publications including Marilyn Palmer and Ian West, *Technology in the County House* (Swindon, 2016).

[4] Personal communication from Michael Symes, 20/03/17; Personal communication from Brent Elliott, 22/03/17.

[5] Mavis Batey and David Lambert, *The English Garden Tour: a view into the past* (London, 1990), p. 7.

photographs have been reviewed as they can reveal the details of tools and equipment used.

Key garden history texts and papers on 18C and 19C gardens such as those from Symes, Jacques, Richardson and Elliott set the scene for individual styles and tastes and highlight the key players in design and innovation. Some include sections on different type of rockwork and describe a progression of different styles.[6] This is outlined in Chapter 2. Related industries such as farming, quarrying, mining and transport give us clues to where the skills, techniques and tools used by rockwork makers probably came from. These are detailed in Chapter 3.

Research methodology

The timeframe was chosen because it was a period of great social, political and economic upheaval. During the Industrial Revolution experimentation, innovation and new ways of thinking emerged.[7] Technology found its way into many areas of life, including garden-making. Over the 200-year period between the first and last gardens considered (1710-1911) many different incarnations of rockwork came, went and reappeared as fashions and ideas changed.

The initial stage of this research was to identify suitable sites where rockwork features had been built within the chosen timeframe. This was done by picking out sites which were identified by experts as having specific features or being at the forefront of changes is styles. Others were added as further examples of individual styles. Basic

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[6] Michael Symes, *The Picturesque and the later Georgian garden* (Bristol, 2012); David Jacques, *Georgian Gardens: the reign of nature* (London, 1990); Tim Richardson, *The Arcadian Friends: inventing the English Landscape Garden* (London, 2008); Brent Elliott, *Victorian gardens* (London, 1986).

[7] Stan Yorke, *The Industrial Revolution Explained* (Newbury, 2014); John Daniels et al., *The real northern powerhouse: the industrial revolution in the North East* (Newcastle, 2015).

information about each site was collected from identified sources. Further details of the database entries are given in Appendix 1.

The second stage was making a series of site visits, involving talking to gardeners and other staff and making a photographic record. The third stage involved filtering out the information and searching for new data to identify details about the construction activity. Individual phases of the construction process were identified, and these headings were used to aid the analysis. This resulted in a range of ‘snippets’ under each heading for each site. These were then collected together to form the details of the research findings, which are analysed in Chapter 4. Evaluation of the findings, answers to the key questions and conclusions are in Chapter 5.

Chapter two
Rockwork forms and styles

The earliest site in the database is the water garden at Upper Park Lodge in Bushy Park, started in 1710. It contained a formal, stepped cascade with faux architectural grottoes either side (Figure 1).[8] The latest site, at Wisley (1911), is a terraced rock garden with a naturalistic cascade and a small cave, made from irregular rocks placed to provide a suitable environment for growing alpine plants (Figure 2).[9] Many different forms and styles of rockwork were built during the intervening 200 years and provided varying construction challenges. The history of rock gardens has been charted in detail and will not be repeated here.[10] Instead a few examples have been chosen to illustrate the range of styles and form to give a context for the construction effort involved.

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[8] Vanessa Remington, *Painting paradise: the art of the garden* (London, 2015), p. 143.
[9] James Pulham, 'Wisley Rock and water garden', *Journal of the Royal Horticultural Society*, Vol 38 (1912-13), pp. 225-233.
[10] See Graham Stuart Thomas, *The rock garden and its plants: from grotto to alpine house* (London, 2004); Scottish Rock Garden Club Forum http://www.srgc.net/forum/index.php?topic=7231.0 [accessed 08/09/17]; Symes, *The Picturesque*; Brent Elliott, 'The British rock garden in the twentieth century', *Occasional Papers from the RHS Lindley Library*, Vol 6 (2011).

Figure 1. Unknown artist, *A view of the cascade, Bushy Park Water Garden*, c1715.

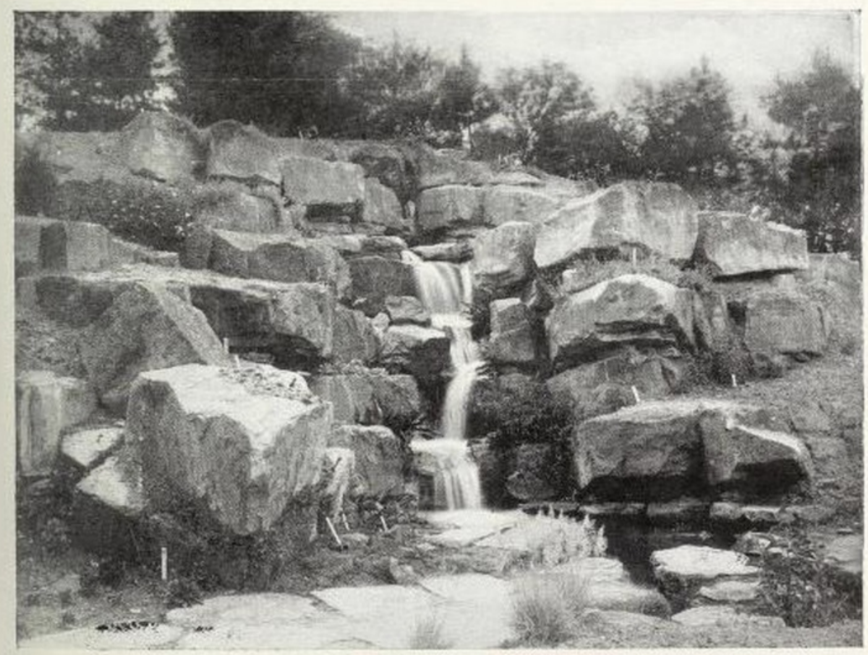

FIG. 74.—THE TOP WATERFALL.

Figure 2. The alpine rock garden at Wisley before planting.

The formal cascade at Bushey Park was followed by other similar constructions. Formal architectural cascades were a speciality of William Kent, particularly those with a triple arch such as his design for Chatsworth in the late 1730s (not built) and Chiswick House for the Earl of Burlington (Figure 3).[11] Flitcroft's cascade at Stourhead, also designed by Kent, follows in this architectural style.[12]

From their formal beginnings, cascades became naturalistic as the 18C progressed, in the same way that gardens moved away from the formality of the previous 200 years. Some utilised existing natural springs and were embellished by judicious addition of rockwork. Examples include Virgil's Grove at The Leasowes and the series of cascades from the Cold Bath at Enville.[13] Others were artificially constructed, often in connection with a dammed lake, such as the one at Virginia Water (Figure 4).[14] Naturalistic cascades continued to be made throughout the 19C utilising both real and artificial rockwork.

Alexander Pope was the first to introduce an underground grotto, utilising the basement of his house in Twickenham, together with a tunnel under the road linking to his garden. In the second phase, 1739-43, it housed a collection of geological curiosities.[15] Others followed his lead including Goldney Grotto and Scotts Grotto (Figure 5). The style lasted throughout the 19C but with less or no decoration.

Rusticated grottos with both external and internal decoration became the norm from 1750. Grottos with 'tufa' decoration augmenting the outside rockwork were built at Painshill and at Croome Court in the

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[11] Symes, *The Picturesque*, p. 90; Andrew Lambirth, 'William Kent was an ideas man – the Damien Hirst of the 18th century', *The Spectator* (12/04/2014), p. 16.

[12] Colin McKewan, (ed.), *Stourhead Lake Project 2005* (Portsmouth, 2006), p. 8.

[13] Michael Symes and Sandy Haynes, *Enville, Hagley, The Leasowes: three great eighteenth century gardens* (Bristol, 2010), pp. 83, 162.

[14] Historic England, 'The Royal Estate, Windsor: Virginia Water', listing 1001177, 1984.

[15] Anthony Beckles Willson, *Alexander Pope's Grotto in Twickenham* (London, 1998), p. 15.

1760s (Figure 6). The inside of the grotto at Painshill broke new ground in being full of sparkling crystals. This was followed by equally lavish decoration in the grotto at Ascot Place (Figure 7).[16] This style of decoration continued until the first part of the next century.

More primitive, unadorned, cave-like grottoes were highly desirable at the peak of the picturesque and sublime era of the later 18C. At Rokeby Park in County Durham an artificial cave 2.5m wide and 2m deep was cut into the cliff to provide a romantic setting above the River Greta (Figure 8). At the end of the century Quarry Bank in Cheshire included a cave-like grotto accessed by steep paths. The style re-emerged in the 19C with similar un-adorned grottos constructed by Pulham at Highnam Court (1847) and Wotton House (Figure 9).[17]

Where a site contained natural rocky outcrops, they were often embellished by man-made additions. Two 18C examples illustrate this style. At Hafod in mid-Wales the seemingly natural wild and rugged landscape was artfully fashioned with the addition of steps and viewing points for visitors (Figure 10). The 300-foot cliffs at Hawkstone, in Shropshire included steep narrow paths, precipices and clefts in the rocks, all hand-cut.[18]

Scattered rockwork, a term coined by Symes to describe clusters of different sized stones placed separately from a cascade or grotto, was first displayed at Painshill on Grotto Island and later at Bowood

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[16] Michael Symes, *Fairest Scenes: five great Surrey gardens* (Elmbridge, 1988), p. 42; Croom Park Grotto http://www.buildingstones.org.uk/search/nprn/site5838 [accessed 16/11/17]; Anon, 'Berkshire Follies', *Foll-e: The Folly Fellowship*, Issue 27 (2010), p. 2.

[17] Historic England, 'Rokeby Park', listing 1000733, 1986; Symes, *The Picturesque*, p. 119; Historic England, 'Highnam Court', listing 1000140, 1986; Historic England, 'Wotton House', listing 1000391, 1984.

[18] George Cumberland, *An attempt to describe Hafod* (London, 1796); Hazelle Jackson, *Shell houses and grottoes* (Oxford, 2001), p. 19; Anna Pavord, 'Gardening: The sublime to the precipitous', *The Independent* (01/04/1994), p. 22.

in the second half of the 18C.[19] An extensive use of this style was created at Swinton in North Yorkshire from 1800 where rocks were placed around the lake edges 'studded like almonds round a trifle' (Figure 11).[20] This style continued to be used throughout the 19C.

Use of rockwork to imitate nature became popular in the 19C. At Hoole House in Cheshire a scale model of the Alps at Chamonix was built in 1826 (Figure 12). The irregular rockwork reached to a maximum of 34 feet.[21] Other scale models followed including the Khyber Pass (East Park, Hull) and the Matterhorn (Friar Park).

The Victorian fern craze of the mid-1800s (pteridomania), together with the availability of cheap glass greenhouses led to rockwork being placed inside ferneries. In the 1870s the Convenor of Bute commissioned a fernery at Ascog, complete with rockwork 'well planted with ferns and alpine plants' (Figure 13).[22] This style of rockwork within a fernery was copied in many places including Swiss Garden in Bedfordshire where artificial stone was used.

Geological accuracy, particularly stratification, became a subject of much debate from the 1850s onwards. Rockwork builders such as Pulham and Meyer, both keen geologists, incorporated stratification in their work while others such as Backhouse did not see it as important.[23] Examples of artificial rockwork by Pulham which showed

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[19] Michael Symes, 'Charles Hamilton at Bowood', *Garden History*, 34.2 (2006), pp. 206-220.
[20] Symes, *The Picturesque*, p. 97; Lorna Cunliffe-Lister, *A Georgian Head Gardener Reports* (Swinton Park, 2010), p. 5.
[21] John Claudius Loudon, 'Hoole House', *The Gardener's Magazine*, Vol 14 (1838), pp. 353-63.
[22] B. S. Williams, 'Ascog Hall', *The Gardeners' Chronicle* (1879), pp. 523-4; Sarah Whittingham, *Fern fever: the story of pteridomania* (London, 2012), pp. 148-151.
[23] Elliott, *Victorian gardens*, p. 97.

stratification include Madresfield Court, built 1876-9, and Dewstow, built from 1895 (Figure 14).[24]

These forms and styles were built on varying terrains – on flat, often swampy ground, on rugged hillsides, within old quarries or underground. Each setting provided its own challenges for the construction process. Many questions follow, such as – how did they support structures up to 40 feet high and how were tunnels and caves cut out of solid rock? The next chapter looks at some of the techniques and equipment available at the time.

[24] Claude Hitching, *Rock landscapes: the Pulham legacy* (Woodbridge, 2012), pp. 104-109, 162-175.

Figure 3. William Kent, *Proposed architectural cascades for Chatsworth*, c1735.

Figure 4. Paul Sandby, *The cascade at Virginia Water*, c1735.
Naturalistic cascade.

Figure 5. Decorated underground grotto at Goldney Garden, Bristol.

Figure 6. Rusticated grotto at Croome Court.

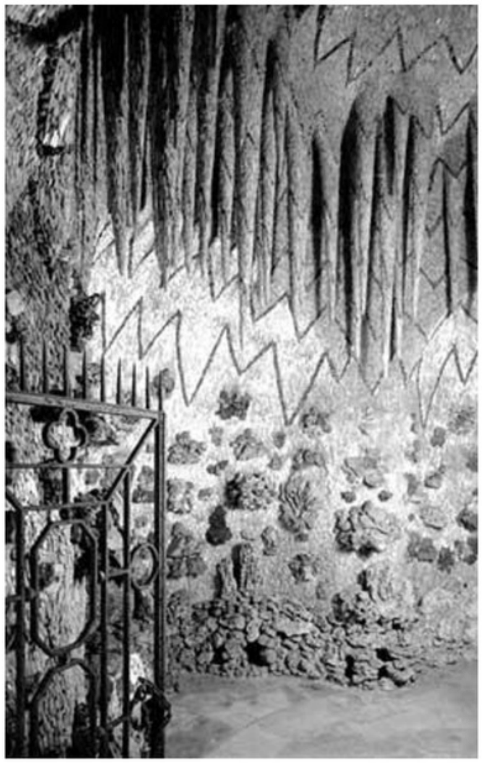

Figure 7. Decorations inside the grotto at Ascot Place.

Figure 8. Undecorated, cave-like grotto at Rokeby Park.

Figure 9. Undecorated grotto at Wotton House, made from pulhamite.

Figure 10. John 'Warwick' Smith, *Pyram cascade entire.*
Embellishment of natural rocky outcrops at Hafod.

Figure 11. Scattered rockwork at Swinton Park.

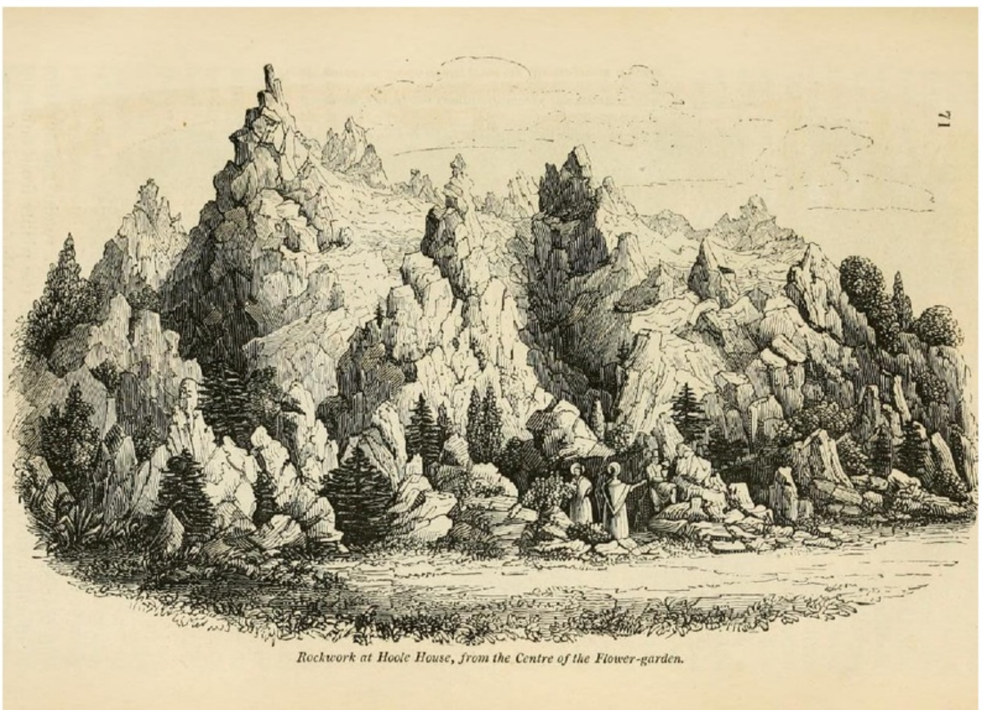

Figure 12. Rockwork imitating nature – scale model at Hoole House.

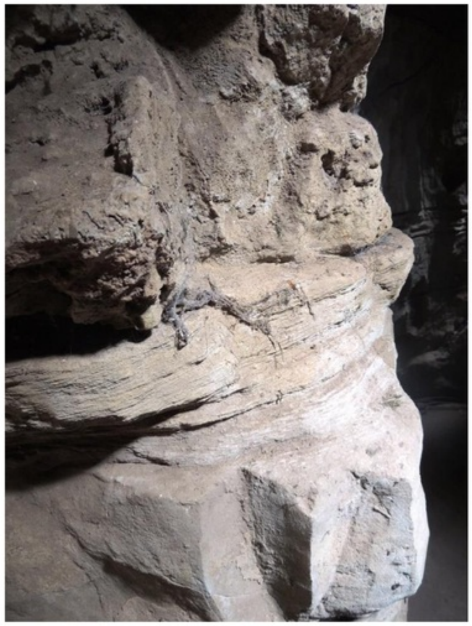

Figure 13. Rockwork by Pulham at Dewstow showing stratification.

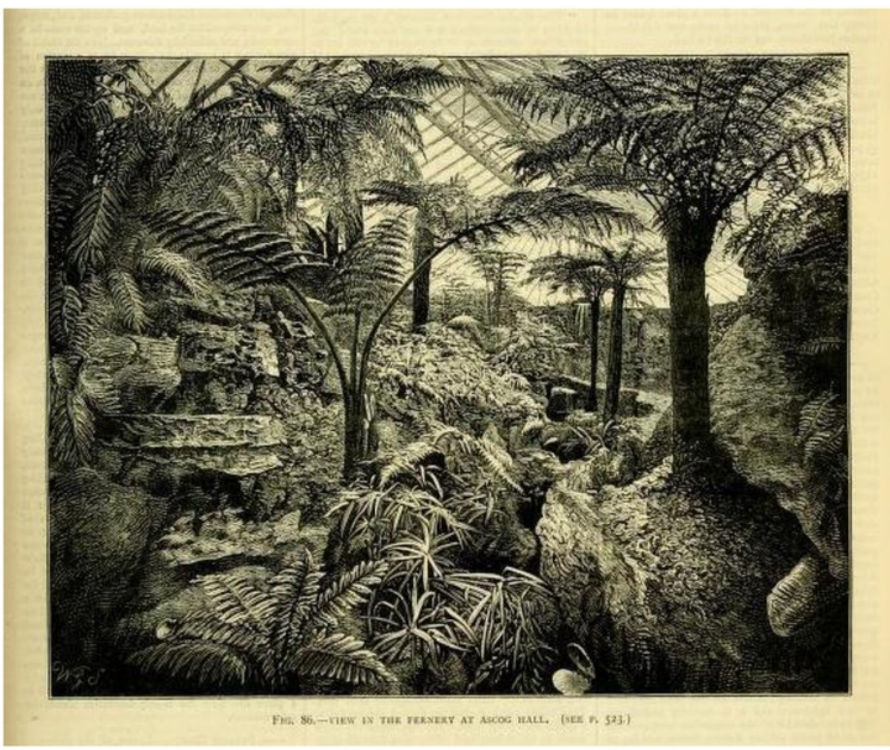

Figure 14. Rockwork within a fernery at Ascog Hall.

Chapter 3
Tools, techniques and technologies.

Where did people designing and constructing rockwork features obtain the appropriate skills, knowledge, tools and techniques? The most likely answer is that they borrowed ideas from contemporary practice in industries such as farming, building construction, mining, quarrying and transport. Large estates usually incorporated one or more working farms and often had temporary quarries on site, suggesting that many of the skills and equipment from these two industries would be known to owners and to their employees. During the 18C and 19C all these industries experienced huge changes in technology as the industrial revolution picked up pace. One key question is whether the builders of rockwork features knew about and chose to utilise these innovations or chose to stick with traditional methods?

Farm labourers in the 18C and 19C would have been experienced in digging ditches and making ponds to aid land drainage. Methods in use at the beginning of the 1700s included ridge and furrow systems, deep trenching and, a bit later, conduits made of flagstones. By the end of the century ceramic pipes were being used and by 1826 the government encouraged more efficient land drainage by removing the tax on tiles and bricks used specifically for that purpose.[25]

In the early 1700s virtually all the implements on farms were hand tools except ploughs, harrows, wagons and carts. Those particularly relevant to rockwork construction were ladders, wheelbarrows, gavelocks (Figure 17), hammers, wedges, axes and chisels. Equipment for moving loads were wagons, wains or carts. Similar

[25] HADAS, 'History of Field Drainage', *Hendon and District Archaeological Society Newsletter* (March 1974), pp. 2-3.

transport mechanisms, using oxen or horse, were used in mining and quarrying (Figure 15).[26]

Figure 15. Two-wheeled cart collecting stone.

The 19C was notable for the introduction of steam traction engines for ploughing, threshing and in sawmills (Figure 16). In 1867 it was estimated that 200,000 acres of arable land was steam tilled.[27]

[26] W. Harwood Long, 'The development of mechanisation in English farming', *The Agricultural History Review*, Vol 11.1 (1963), p. 17; Arnold James, *Farm waggons and carts*, (Exeter, 1977).
[27] Long, 'Mechanisation in English farming', p. 20.

Figure 16. 19C Fowler steam plough.

From the early 1700s onwards the stone quarrying industry expanded as the need for stone buildings increased. By 1857, 3,000 quarries were listed, most of which distributed their products via the newly established rail network.[28] Common hand tools used in quarrying throughout the 18C and 19C included a quarry pick, wedges and various types of chisel, which were struck with a metal hammer or a wooden mallet (Figure 17). In addition, pickaxes or crowbars were widely used in both mines and quarries. These were all tools that had been used for centuries with little change.[29]

Rock-getters extracted rock by cutting rows of holes along the marked-out block. Wedges were then hammered into the holes to split it, allowing the block to be freed with crowbars/levers (Figure18).[30] This method had been used for hundreds of years and

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[28] Graham Lott, 'The building stone industry in Britain past and present'. <www.englishstone.org.uk> [accessed 08/12/2017].
[29] W. Wooton, B. Russel & P. Rockwell, 'Stoneworking tools and toolmarks'. <http://www.artofmaking.ac.uk/content/essays/2-stoneworking-tools-and-toolmarks-w-wootton-b-russel-p-rockwell/> [accessed on 12/02/2018].
[30] Anon, 'The rock-getters'. <http://www.valleyofstone.org/schools/quarryworked > [accessed 08/12/2017].

is still used today but with the aid of power tools rather than the hammer.

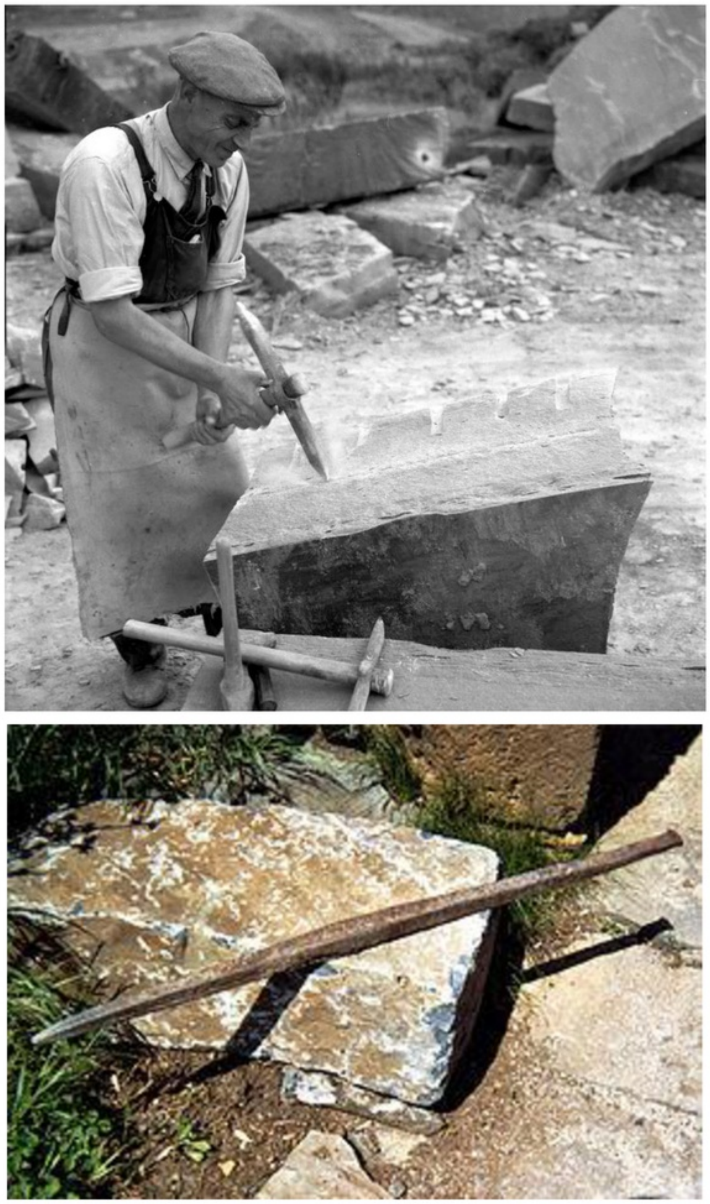

Figure 17. Quarryman with pickaxe and hammer (top) and gavelock (bottom).

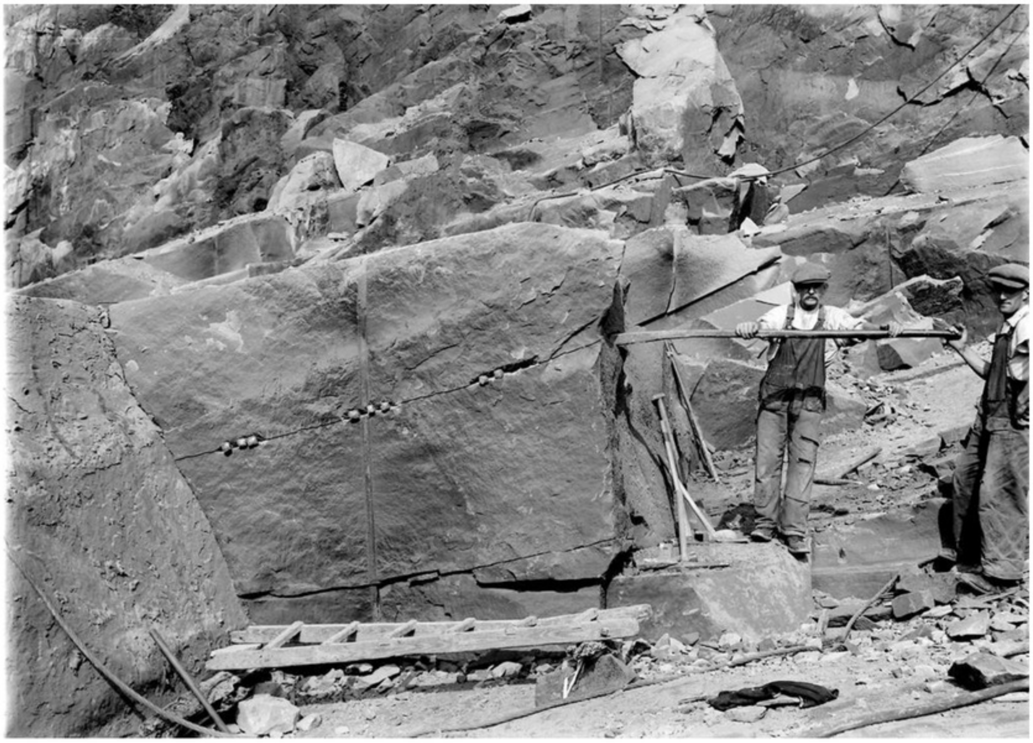

Figure 18. Splitting rock using wedges and lever.

The simplest aids for lifting and moving heavy stones away from the quarry site were levers, rollers and jacks (Figure 19) plus a windlass (or winch), powered by man, horse or donkey (Figure 20). In the 19C winches were made of cast iron with gears and a brake, using a chain or later a wire rope (first used in 1830s). They could be anchored to any point for hauling stone into position.[31]

[31] Peter Stanier, *Stone quarry landscapes: the industrial archaeology of quarrying* (Stroud, 2000), p. 26

Figure 19. Workmen load large logs onto a river barge using a jack (centre of picture, jack operated by 2nd man from left). A second jack lies on the canal edge.

Figure 20. Old winch at a quarry in Durlston, Dorset, with a vertical axis. This would have been powered by a horse or donkey.

Materials such as coal, tin, limestone and sand have been mined in Britain for centuries. Before the 18C coal was only mined near the surface in bell pits (Figure 21). No propping was used to support the roof. In some mines the coal was carried up ladders to the surface by women and children, in others it was carried in a trug-basket and lifted by a windlass (Figure 22).

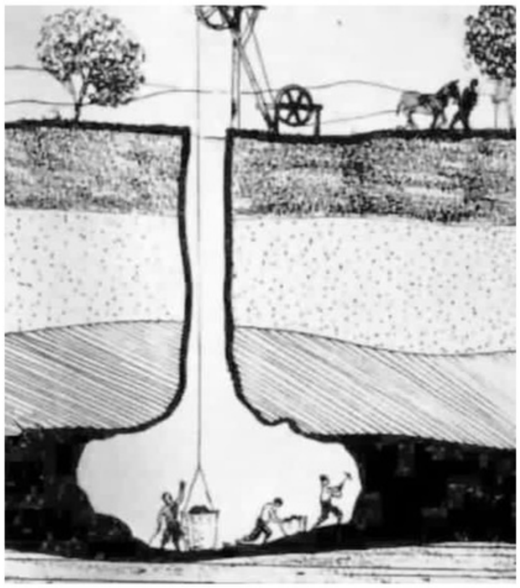

Figure 21. Drawing of an early bell-pit with a horse lifting the tubs of coal.

Figure 22. 18C painting by Paul Sandby showing a windlass in use to lift water from a well.

Another early mining technique was 'pillar and stall' where pillars were retained to support the roof and coal was extracted around the pillar (Figure 23).[32] Between 1700 and 1900 coal production increased from 2.7 million tonnes to 250 million tonnes, the growth fuelled by use of steam engines and industrialisation.[33]

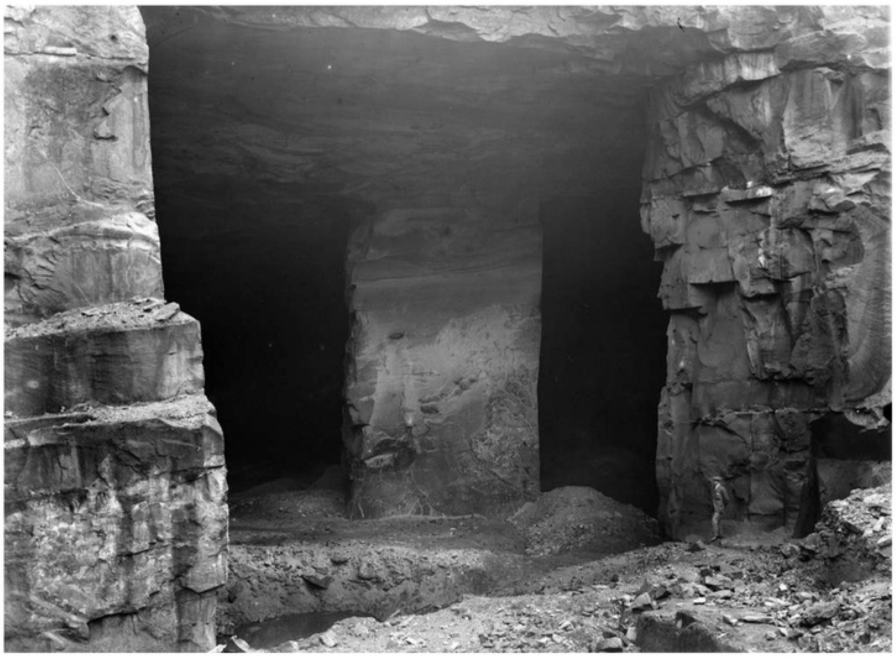

Figure 23. Pillar and stall method at Huntershill Quarry, Glasgow.

The first machines used in 18C mines were steam powered engines designed to pump water out, allowing shafts to be sunk to access deeper seams. The coal was dug using a hand pickaxe and shovel, loaded into a tub or corve and then hand-pulled/pushed using sleds or along rails to the shaft, then lifted to the surface by a horse and gin (Figure 24). It was not until the late 19C that steam driven engine houses brought men and coal to and from the surface.[34]

[32] Paul W. Sowan, 'Mining and subterranean quarrying in Sussex', *Sussex Industrial* History, Issue 14 (1984), pp. 25-39; A Russell, 'Pillar and Stoop Coal Mining'. <https://www.hoodfamily.info/coal/stoop.html> [accessed 08/12/2017].

[33] C. N. Truman, 'Coal mines in the industrial revolution'. <https://www.historylearningsite.co.uk/britain-1700-to-1900/industrial-revolution/coal-mines-in-the-industrial-revolution/> [accessed 12/01/18].

[34] Anon, 'Making sense of coal mining'. <https://www.ncm.org.uk/learning/learning-resources/mining-factsheets> [accessed 08/12/2017].

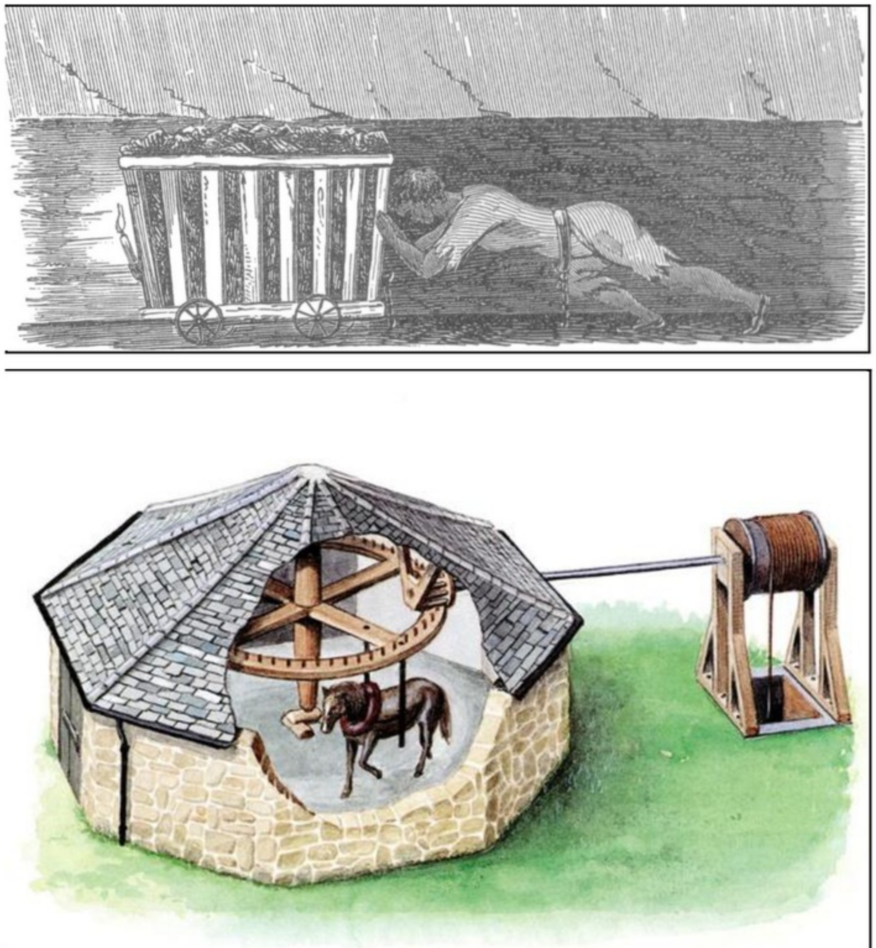

Figure 24. Pushing a corve along to the coal shaft (above) and a horse and gin (below).

Building construction was one of the oldest crafts. Medieval cathedrals were constructed in stone and bricklaying was common from Tudor times. At the beginning of the 18C, instruments such as a surveyor's chain, a circumferentor and ranging rod were in regular use (Figure 25).[35] By then end of the 1700s the theodolite became the surveyor's instrument of choice.

[35] Finnian O'Cionnaith, 'Land surveying in eighteenth and early nineteenth-century Dublin', (unpublished PhD thesis, National University of Ireland Maynooth, 2011), pp. 113, 123.

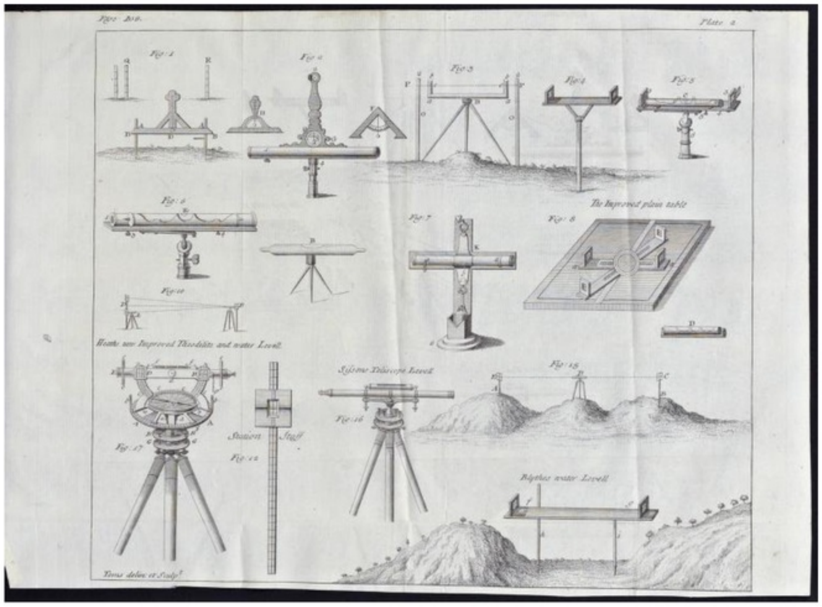

Figure 25. Early 18C surveying tools.

Scaffolding and ladders have been used since buildings were first constructed. Medieval drawings show wooden ladders and scaffolding supporting the construction of stone cathedrals.[36] Scaffolding was formed from wooden poles lashed together with hemp rope (Figures 26, 27). Designs and materials did not change significantly until the early 20C when the scaffixer was invented.[37]

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[36] Alain Erlande-Brandenburg, *The cathedral builders of the Middle Ages* (London, 1995), p. 127.

[37] Anon, 'The History of Scaffolding'. <http://www.scaffoldersforum.com/showthread.php?2089-The-History-of-Scaffolding> [accessed 13/02/2018].

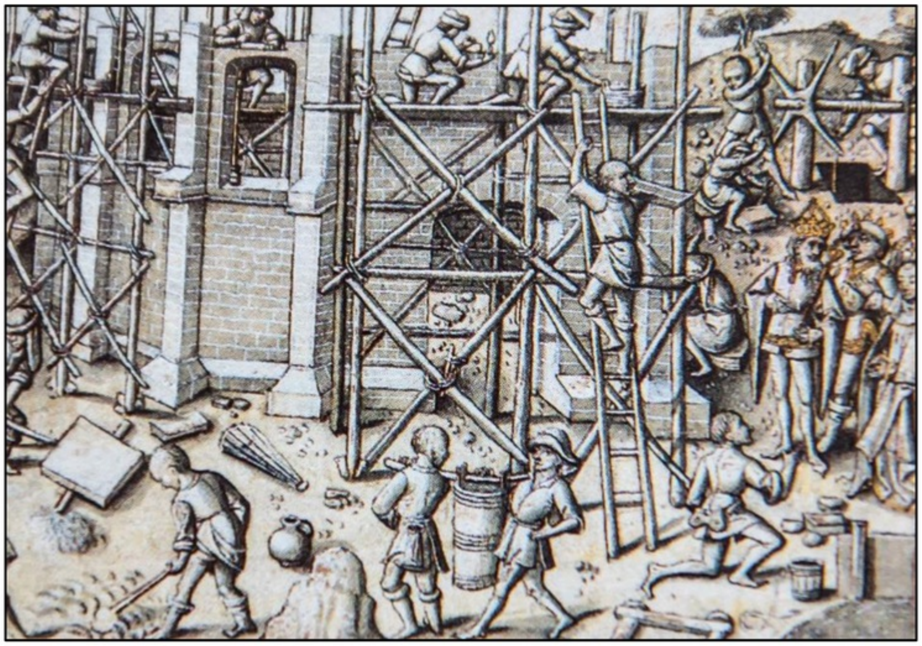

Figure 26. 15C wooden scaffolding and ladder.

Figure 27. Wooden scaffolding and ladder used in1853 house construction.

The literature about handling and moving heavy loads, including rocks, comes mostly from studies of the construction of medieval cathedrals and from industrial archaeology.[38] All implements used for lifting heavy loads in the 18C/19C were still formed of basic components defined by Renaissance scientists (lever, wheel and axle, pulley, inclined plane, wedge and screw). Wheelbarrows, first invented by the Chinese nearly 2000 year ago, were first used in Britain in the 13C for building construction, mining, quarrying, agriculture and gardening. Those used in 18C and 19C differed little from their medieval cousins (Figure 28).[39]

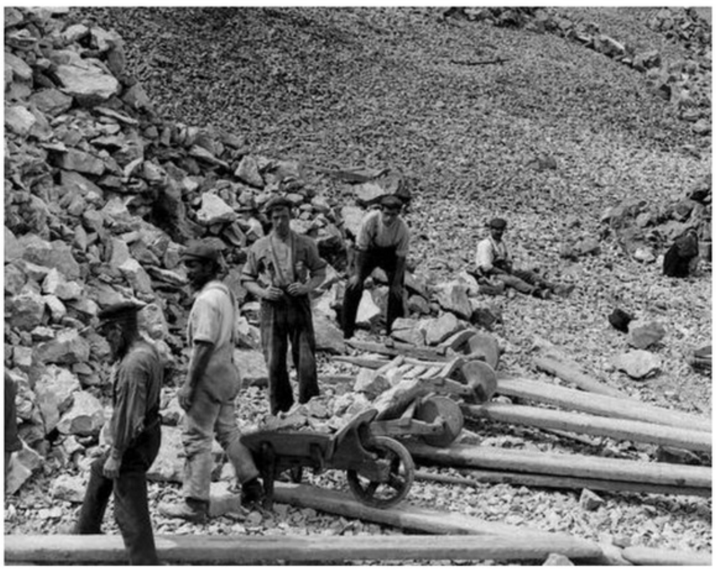

Figure 28. 19C wooden wheelbarrow being used in a quarry.

The key pieces of equipment were varying types of crane together with a block and tackle and some means of grabbing the stone. The earliest apparatus was called sheer-legs (Figure 29). They could

[38] Anon, 'Moving the stones of Baalbeck – the wonders of Roman engineering'. <https://gilgamesh42.worldpress.com/moving-the-stones-of-baalbeck-the-wonders-of-roman-engineering/> [accessed 28/02/2017].

[39] Toby Musgrave, 'The noble ancestry of the wheelbarrow', *The Telegraph* (17/11/2001), p. 23; David Marsh, 'The wheelbarrow … a weapon of war?'. <https://thegardenstrust.blog/2015/02/28/the-wheelbarrow-a-weapon-of-war/> [accessed 06/09/2018].

easily be moved from place to place and positioned over a stone to lift it high enough to be loaded onto a wagon.[40]

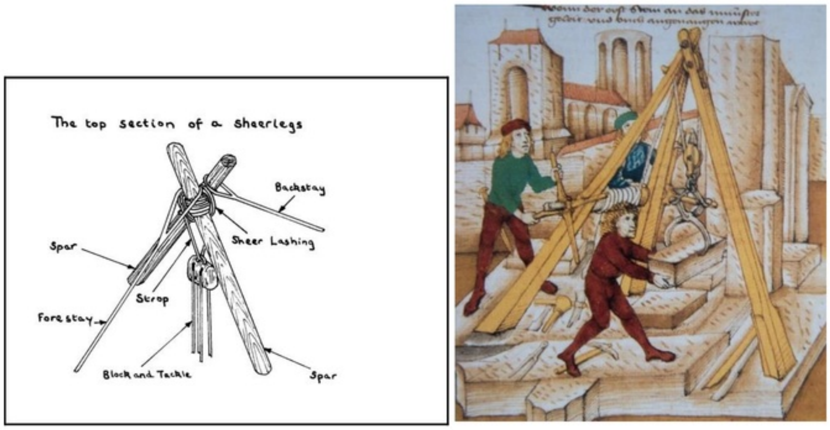

Figure 29. Sheer legs diagram (left), 15C image of sheer legs in use (right).

The earliest timber cranes developed into the derrick crane with a jib fixed to an upright mast supported by 2 or 3 wooden stays (Figure 30). The mast and jib could rotate together swinging the load from side to side. A hand winch was attached to the base of the jib and they could lift up to 20 tons.[41] The stone had to be attached to the crane's hook for lifting – one method was to use a chain sling underneath the stone or a lewis could be fitted into a hole in the top of the stone (Figure 31).[42]

[40] Stanier, *Stone quarry landscapes*, p26.
[41] Anon, 'Cranes'. <http://www.valleyofstone.org.uk/journey/menandmachines/cranes> [accessed 04/12/2017].
[42] Stanier, *Stone Quarry Landscapes*, p. 28.

Figure 30. Derrick cranes in use in a Dorset quarry.

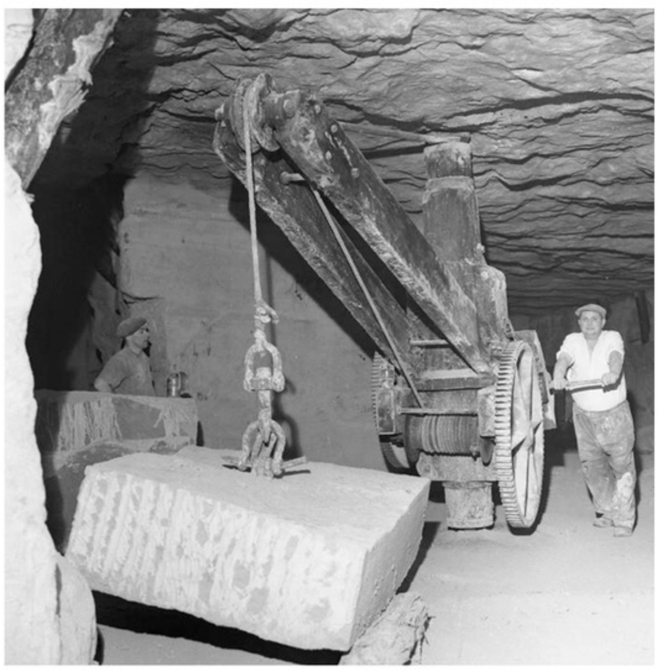

Figure 31. Hand crane operating underground. Note the lewis fitted to the block of stone.

From the middle of the 19C powered cranes came into use, initially using hydraulics then steam then compressed air. In 1795 Joseph Bramah used hydraulics to produce rotary motion and forty years later, William Armstrong produced the first hydraulic dock crane (Figure 32). Soon after steam-powered cranes became available.[43]

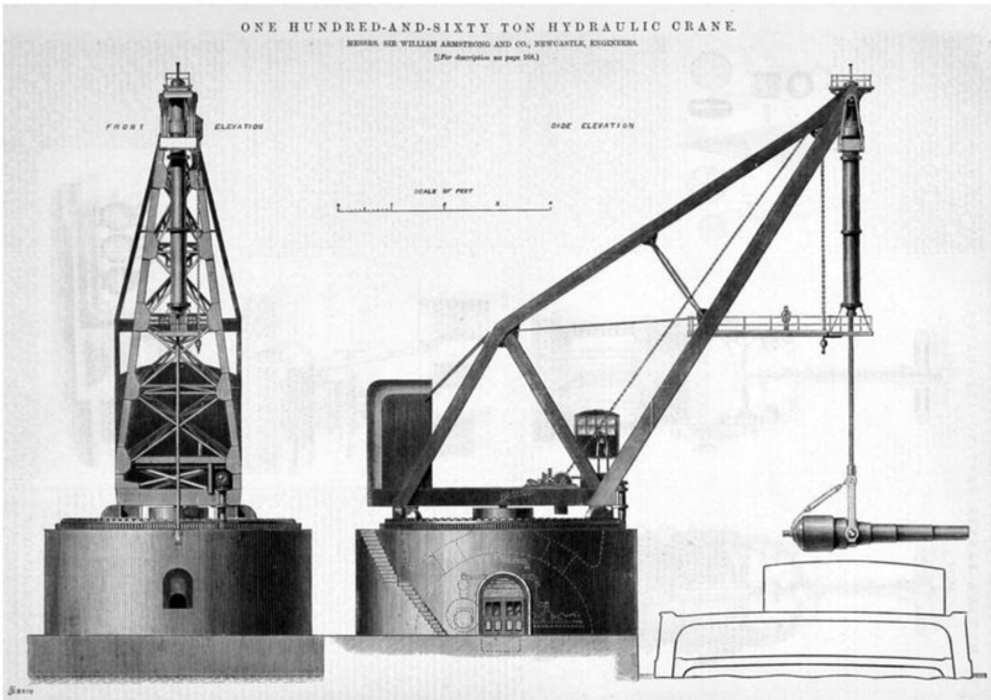

Figure 32. Armstrong 160-ton hydraulic crane.

Quarries and coal mines needed connections to the nearest transport route to get their product to customers. The earliest method was to use waterways – rivers or the sea. Rivers had provided the rudiments of a national transport system since Roman times but problems from obstructions and silting up meant that many were not navigable for very far upstream. These problems led eventually to the introduction of man-made rivers in the form of canals.

In 1760 the first canal in Britain, the Bridgewater Canal, was commissioned to carry coal from a mine to Manchester. A horse towing a boat with a rope could pull fifty times a much cargo as it

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[43] Ian McNeil, *Hydraulic Power* (London, 1972), p. 35; Peter Barlow, '*Treatise on the Manufactures and Machinery of Great Britain*' (London, 1836), p. 234.

could pull in a cart or wagon on roads (Figure 33).[44] During the construction of the Manchester ship canal in the late 1880s steam cranes and mechanical bucket excavators were used but they could only work with loose earth (Figure 34). Where rocks were embedded in the soil, excavations were done by hand using shovels, picks and wheelbarrows.[45]

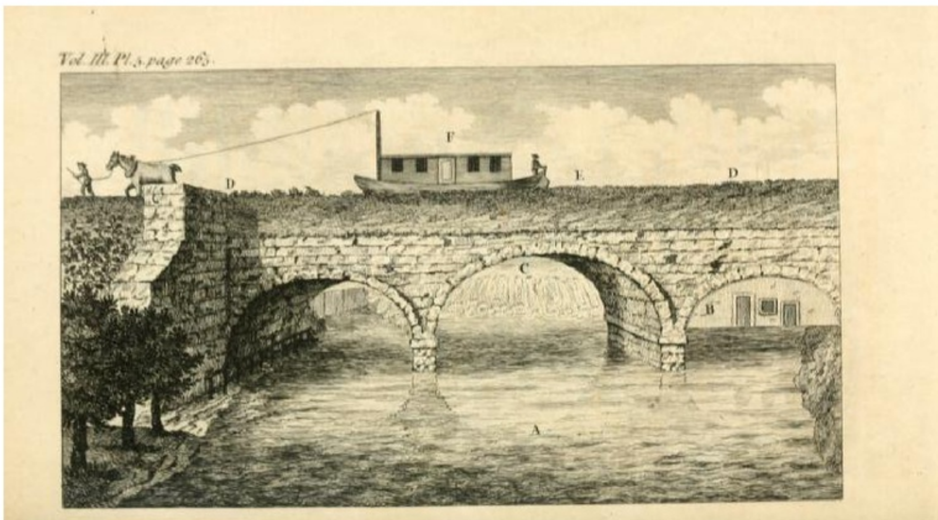

Figure 33. Horse drawing a barge along a canal. 1770 drawing.

[44] Kenneth Falconer, *Canal & River navigations national overview. Research Report No 28* (Swindon, 2017); Anthony Burton, *Canal 250: the story of Britain's canals* (Stroud, 2011), p. 78.
[45] Liz McIvor, *Canals: the making of a nation* (London, 2015), p. 181.

Figure 34. Steam-driven trencher in 1880s, used in Katrine aqueduct construction, Scotland.

At the beginning of the 18C roads were in a poor state, following the massive increase in wheeled vehicles during the previous 100 years. Technical improvements were made during the 1700s using layers of stone and compaction, supported by the introduction of 'turnpikes' from 1750s.[46] The proceeds were used to pay for maintenance. By the mid-1830s over 20,000 miles of roads were controlled by turnpike trusts. By 1902 a tarmacadam road surface was ready to receive motorised vehicles (Figure 35).[47] Throughout this period roads were used extensively for moving goods from ports, canal termini and railway stations to the end user (Figure 36).

[46] Anon, 'A brief history of road building, Chapter 10'. <http://gerald-massey.org.uk/Tring/c_chapter%2010.htm> [accessed 21/01/2018].
[47] Dan Bogart, Turnpike roads of England and Wales, <http://www.campop.geog.cam.ac.uk/reserch/projects/transport/onlineatlas/britishturnpiketrusts.pdf> [accessed 22/01/2018].

Figure 35. Labourers laying substrate of new macadam road surface with the aid of a steam roller, Oxford c1900.

Figure 36. Transporting Portland stone by road in 1805 using a two-wheeled 'jack'. Horses at the rear acted as the braking system. This method was superseded by the steam driven traction engine later in the century.

There were many early railways prior to the locomotive period of steam trains in the 19C. The earliest recorded, in the second half of the 16C, were short lengths of wooden rails, sometimes called tramways, laid inside coal mines. Then came wooden wagonways from the early 17C, built to connect a mine shaft to a wharf on navigable water. From their beginnings in coal mining their use spread to other industries.[48]

The first complete 'industrial handling system' to serve an extractive industry was Ralph Allen's wooden railway near Bath in 1731 (Figure 37). It connected his Combe Down stone quarries to the river Avon,

[48] David Gwyn and Neil Cossons, 'Early railways in England: review and summary of recent research', *Historic England Research Report Series*, 25 (2017), pp. 20, 22.

where there were cranes and river boats to take the produce to the port at Bristol. Loaded trucks, complete with a braking system, ran on wooden tracks down the gradient of 1:10 by gravity and were then pulled by two horses on the level and back up the hill (Figure 38).[49] Subsequent developments led to the use of iron on tramways such as at the Coalbrookdale Iron Works (1760). These changes reduced the friction and made it easier to transport larger loads.[50]

Figure 37. Ralph Allen's tramway from Coombe Park quarry to the river Avon.

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[49] Gillian Clarke, *Prior Park: a compleat landscape* (Bath, 1987), p. 12; Colin Maggs, *Steam trains: the magnificent history of Britain's locomotives from Stephenson's rocket to British Rail Evening Star* (Stroud, 2014), p. 8.

[50] The Stephenson Locomotive Society & Waggonway Research Circle, 'Timeline for early railway developments'. <http://www.stephensonloco.org.uk/time_line.htm> [accessed 08/12/2017].

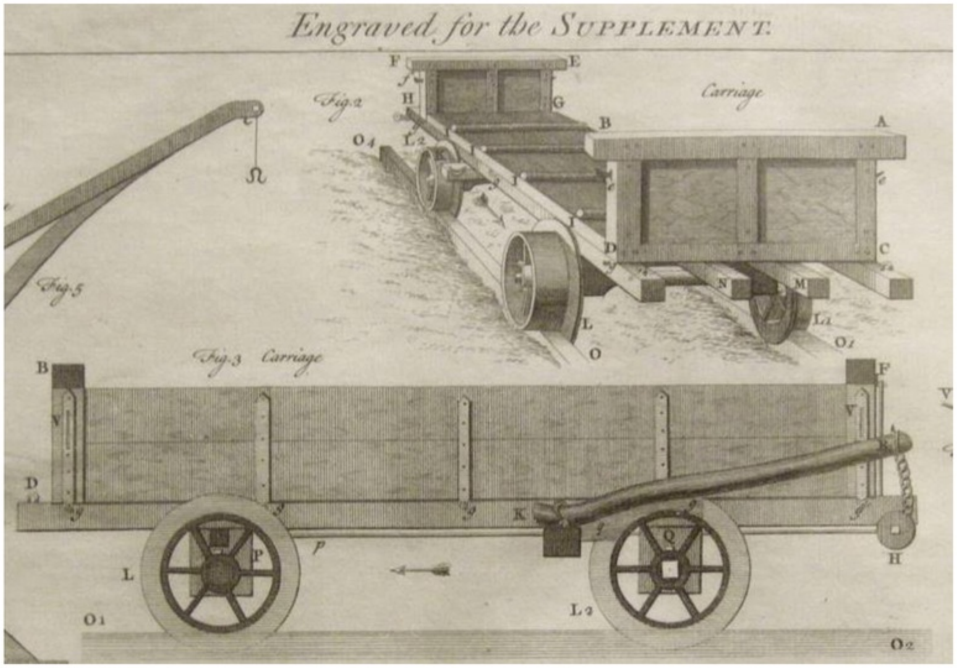

Figure 38. Details of the carriages used in Ralph Allen's tramway, produced by John Padmore.

From 1805 the early railways were powered by steam, initially static steam engines operating inclined planes. This changed in 1825 when the Stockton & Darlington railway opened. It was 26 miles long and ran from collieries to wharfs at Stockton on Tees where the coal was loaded onto sea-going vessels.[51] During the Victorian era the railways expanded exponentially – from 378 miles of track in 1836 to 13,500 miles in 1870.[52]

The earliest railway tunnels constructed in the late 1700s, were 'cut and cover' types at Flockton and Fritchley on the Butterley Gangroad. The area was excavated, then the tunnel structure was built in the hole, and finally filled in over the top.[53] Construction of the

[51] Gwyn and Cossons, 'Early railways', pp. 27, 84.
[52] Dan Bogart et al., 'The development of the railway network in Britain 1825-1911'. <https://www.campop.geog.cam.ac.uk/research/projects/transport/onlineatlas/railways.pdf > [accessed 8/12/2017].
[53] Gwyn and Cossons, 'Early railways', p. 29.

canal and railway infrastructure was extremely labour-intensive as nearly all excavations were done by hand (Figure 39).[54]

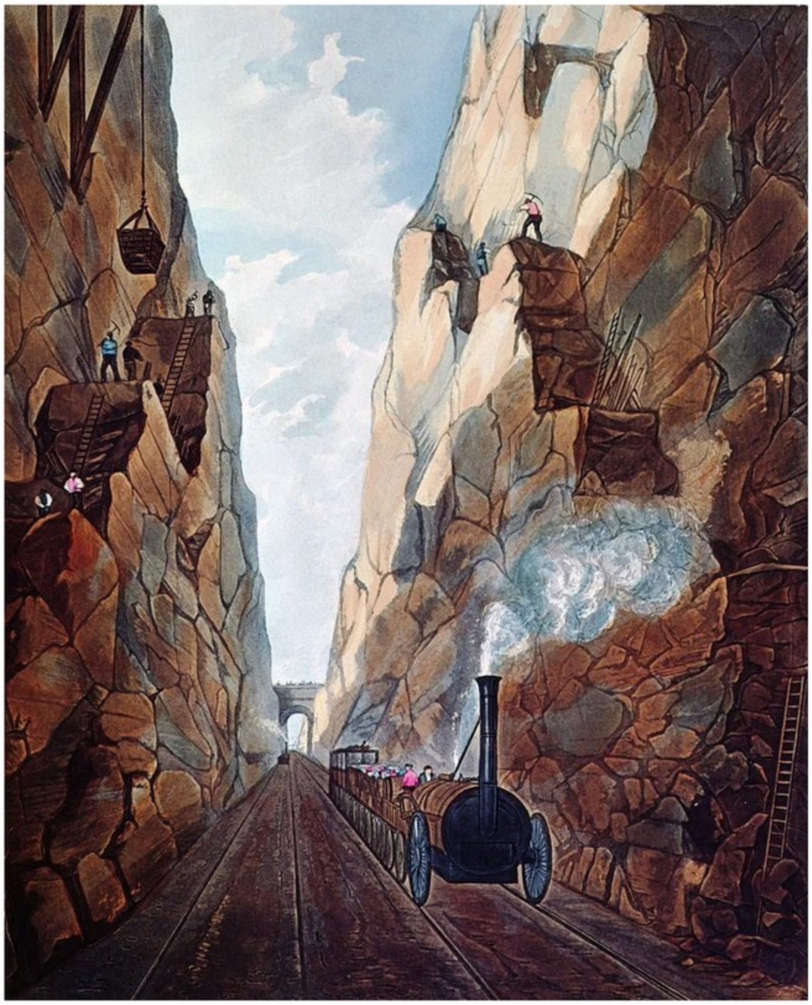

Figure 39. T. T. Bury, *Excavation of Olive Mount, 4 miles from Liverpool*, 1831. Note the navvies hacking the rock with pickaxes.

Mortar, used to bind building blocks such as stone or bricks, dates back over 8,000 years. Initially it was made of mud and clay but from medieval times onwards lime mortars were used in Britain.[55] In the

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[54] Construction News, 'The men who built Britain's canals and railways by hand'. <https://www.constructionnews.co.uk/home/the-men-who-built-britains-canals-and-railways-by-hand/890531.article> [accessed 29/01/2018].

[55] Cemex Mortars, 'Experts in mortar: educational guide'. <https://www.cemex.co.uk/documents/45807659/45840198/mortar-intro-to-mortar.pdf/cc12caec-4dc4-310e-4fff-57c96efb8f1b> [accessed 08/12/2017].

18C experimentation with different mixes led to early forms of artificial stone, mostly used in garden decorations.[56] These early products were clay-based so were not directly relevant for rockwork features.[57]

The 19C was notable for its introduction of new materials which provided new possibilities in garden construction. Concrete for foundations was pioneered by Smirke in 1817. Its use in gardens began in the 1840s and by the 1870s gardeners were engaging in pond-concreting competitions. This was the era of developments in cement-based artificial stone. When the patent for Portland cement was taken out in 1824, Lockwood had been using his version of Portland stone cement for three years. An employee of his, James Pulham went on to become the most famous artificial stone maker of the century, marketing Pulhamite for all styles of rockwork features (Figure 40).[58] In Pulham's trade brochure of 1877 he writes about their mode of working and lists the sites worked on.[59] More recently Hitching has written extensively about Pulham's work, including their construction methods.[60] Cast and wrought iron competed with each other until the commercial introduction of Bessemer's steel process in the 1880s.[61] These and other developments provided rockwork builders with a greater choice of materials.

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[56] Richard Holt, *A short treatise of artificial stone* (London, 1730).
[57] Parks & Garden UK, 'Eleanor Coade – artist in artificial stone'. <http://www.parksandgardens.org/explore/topics/176-historical-profiles/524-eleanor-coade-artist-in-artifical-stone > [accessed 12/12/2017].
[58] Sally Festing, 'Recent discoveries and restoration of Pulham Sites', *Garden History*, 25.2 (1997), p. 236.
[59] James Pulham, *Picturesque Ferneries and Rock Garden Scenery* (London, 1877), p. 32.
[60] Hitching, *Rock Landscapes*, pp. 61-234.
[61] Elliott, *Victorian gardens*, p. 16.

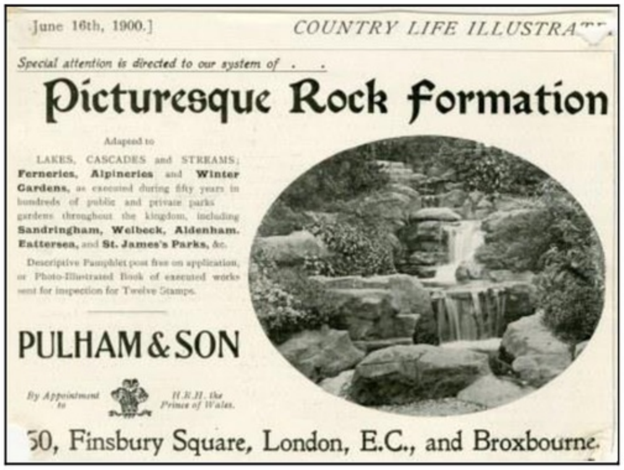

Figure 40. James Pulham & Son advertisement 1900.

This overview has identified tools, techniques and materials used in a variety of industries which may have been ‘borrowed’ by people building rockwork features in gardens. The next chapter identifies which if any were used.

Chapter 4
Research Findings

Farrer suggested that rockwork designers/builders should be 'as much an architect as he who designs houses'.[62] Were techniques from building construction as well as allied industries utilised in creating rockwork structures? The key stages in house-construction throughout the 18C and 19C were choosing the site, procurement of materials, surveying and setting out, making designs/plans, excavation, foundations, building the core, and final fix – adding decorations. To help answer the question, this chapter sets out research findings under each of these headings, drawn from individual site information in the database as well as recent restorations and archived photographs of construction operations. The final sections look at construction techniques specific to rockwork features and the tools and equipment used together with a detailed consideration of the construction of the rock garden at Wisley as a comparator.

Choosing the site

The starting point was choosing a site. Most country estates were chosen for their good hunting or good agricultural land and not for the availability of rock. Thirty six percent of sites considered were situated on unsuitable bedrock (chalk, clay, sand or mudstone) implying they would have imported rocks for their construction. Most of these sites were in south or south-east England with a few exceptions such as East Park in Yorkshire (clay and silt over chalk), Elvaston in Derbyshire (mudstone) and Highnam Court in Gloucestershire (mudstone).[63] The desire to make rockwork features was sufficient to overcome the extra expense involved in importing suitable stone.

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[62] Reginal Farrer, *My Rock Garden* (London, 1908), p 8.
[63] See Appendix 1, Table 3 for list of local bedrock using British Geological Survey maps and postcode.

Procurement of materials

Procurement of suitable materials was and is a key part of any construction project. For rockwork structures the main materials were the rocks themselves, decorative additions, fixing materials and materials for the core structure. In the case of artificial stone, the key components were the specific mortars used and material to make the core to which the final finish was applied. The procurement options available were to obtain the materials on site or nearby, to purchase them from a contractor or to use contacts and friends to obtain them on your behalf. Examples of chosen rock are given in the table below.

Table 1: chosen rock type used for building rockwork

Rock type	No. Sites	Examples
None suitable on site	30	Claremont, Surrey (1750) – sandstone & granite imported Syon Park (1830) – granite imported
Sandstone	40	Hawstone, Shropshire (1750) – on site Chatsworth, Derbyshire (1842) – on site Wisley, Surrey (1911) - imported
Limestone	22	Fonthill (1794) – grotto – imported Gnoll, Neath (1720) – grotto ceiling – local
Granite	3	Pencarrow, Cornwall (1831) – grotto - local
Tufa or spongestone	17	Painshill, Surrey (1760) – imported Hackfall, Yorkshire (1794) – real tufa on site Wardour Castle (1792) – imported
Artificial	15	Swiss Garden, Bedfordshire (1876) – grotto - faux tufa The Dell, Surrey (1888) – rock scenery - pulhamite
Note: sites often used several different materials. See Appendix 1 for more details.		

Recycling was used extensively during both centuries. The two key sources were industrial waste and old building materials. During the 18C availability and use of waste materials from industrial processes grew in line with the industrialisation of the country, particularly in grotto construction where their shiny colour or rough texture was admired. An early example was Warmley House (1746), where William Champion used the purple-black slag from his brass foundry (on-site) to make indestructible building blocks to construct his underground caverns, tunnels and grotto. It is the only grotto completely constructed using industrial waste.[64]

From the iron industry came 'banded turquoise furnace slag' used in the grottos at Hagley and Hawkstone, or the 'slag-lined' passage at Ascot Place.[65] The steely waste from inside the ladle, called 'scull iron' was used at Oatlands.[66] Melted glass was used at Scott's grotto and clinker (a stony residue from burnt coal or from a furnace) used at East Park in Hull, and later Friar Park.[67] Clinker bricks, named for the distinctive sound the hard bricks made when banged together, were the waste from brick-making when left too close to the heat of a coal-fired kiln. This sort of clinker was used extensively in the 19C, from home-made 'rockeries' in small back yards to the core for the 'Pulhamite system' of artificial stone.[68]

An alternative form of recycling was to re-use stone from the remains of earlier buildings. Examples from the 18C include Halswell (rubble from a late 17C banqueting house), Chelsea Physic Garden (stone from the Tower of London) and Wardour Castle (Neolithic remains).[69]

Where suitable materials could be found on site or nearby, they were chosen to save on transportation costs and to ensure the rockwork features looked 'natural' for their setting (although some designers

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[64] Atkins Heritage, *Champion's brassworks and gardens: Conservation Management Plan* (Bristol, 2007), p. 137.

[65] Symes and Haynes, *Enville, Hagley, The* Leasowes, pp. 72, 122; Walding Associates, *Hawkstone Park Follies: a short history and guide* (Hawkstone, 2011), p.15; Andrea Walker, 'Ascot Place restoration'. <https://www.andreawalkerconservation.wordpress.com/2011/12/19/way-down-in-the-grotto/> [accessed 04/12/2017].

[66] Michael Symes, 'New light on Oatlands Park in the eighteenth century', *Garden History*, 9.2 (1981), p. 146.

[67] David Perman, *A new guide to Scott's Grotto*, (Ware, 1991) p. 4; Historic England, 'East Park, Hull', listing 1001519, 2001; Historic England, 'Friar Park', listing 1000504, 1984.

[68] C. Beresford and D. Mason, *Durability Guaranteed: Pulhamite rockwork - its conservation and repair* (Swindon, 2008), p. 8.

[69] Roy Bolton, 'The Temple Bridge'. <https://halswellpark.wordpress.com/2016/03/30/the-temple-bridge/> [accessed 08/09/18]; Jackson, *Shell houses and grottoes*, p. 19.

did not worry about this). It is not surprising, therefore, to find the use of gritstone (a type of sandstone) at Chatsworth and other Derbyshire gardens, limestone in gardens of North Yorkshire and granite at Pencarrow and other gardens of Devon & Cornwall.[70]

Bricks were often made on site where local subsoil included clay deposits as at Painshill, where Charles Hamilton use them for his grotto construction.[71] Where the bedrock was suitable, temporary quarries were made, often to extract stone for building materials for the house but also for rockwork. At Stancliffe Hall in Derbyshire, the home of Joseph Whitworth, the quarries on the estate were used in constructing his natural rockwork 'of the most stupendous nature' (Figure 41).[72]

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[70] Contemporary accounts were cross checked against British Geological Survey maps from site postcodes via Geology of Britain Viewer. <http://mapapps.bgs.ac.uk/geologyofbritain/home.html> [accessed 14/09/2017].

[71] Michael Symes, *Mr Hamilton's Elysium: the gardens of* Painshill (London, 2010), p. 46.

[72] Dianne Barre, *Historic Gardens and parks of Derbyshire* (Oxford 2017), p. 175.

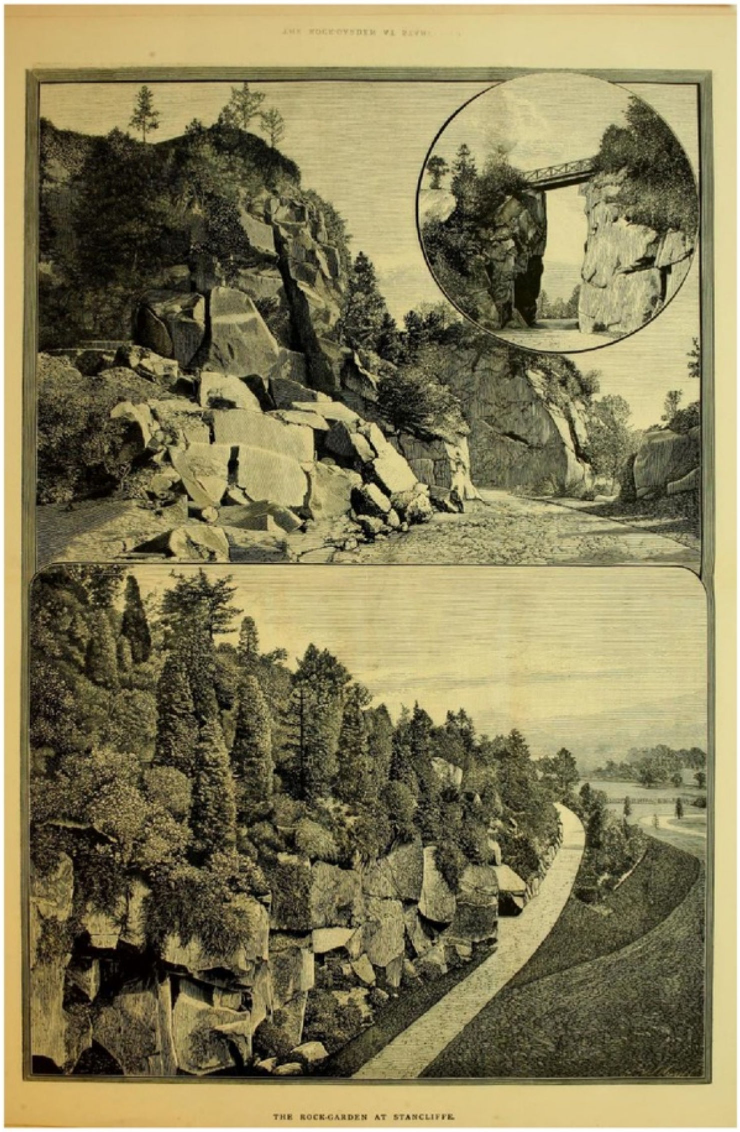

Figure 41. Rockwork at Stancliffe Hall, Derbyshire, 1884.

If there were existing rocky outcrops on site, they were exploited by excavating around them or by cutting into the rock to create features such as steps or caves. Examples include Plumpton Rocks (1755) where the dramatic outcrop of millstone grit was ‘improved’ by the addition of a lake and seats cut into the rock. At Glen Andred (1865) in Surrey, Edward Cooke embellished his natural rocky outcrops of sandstone by excavating around them.[73]

Rocks were also collected from nearby open moorland or beauty spots, something that today would be considered environmental vandalism. Sir William Molesworth used granite boulders from Bodmin Moor, about 10-15 miles away, for his rock garden at Pencarrow (1831). The stones were arranged in imitation of the natural scenery of the moors and surface vegetation was carefully retained.[74] Later, at Aysgarth in North Yorkshire huge, waterworn limestone blocks were collected from Stephen's Moor about half a mile away from the garden and at Cragside 'fell sandstone' was brought in from the surrounding moors and placed to show its weathered sides (Figures 42, 43).[75]

Figure 42. Limestone rock at Stephen's Moor, near Aysgarth.

[73] Anon, 'Edward W. Cooke, R.A. Obituary', *The Gardeners' Chronicle* (1880), p. 41.
[74] Historic England 'Pencarrow', listing 1000652, 1987.
[75] Rosemary Anderson, *Aysgarth Edwardian Rock Garden* (Aysgarth, 2014), p. 40; Hugh Dixon, *Cragside* (Swindon, 2017), p. 34.

An outside contractor would sometimes supply the rocks where the site did not contain any suitable material, or an owner would know of a suitable source from contacts in Britain or abroad. Records show that Backhouse brought tons of millstone grit (a type of sandstone) from Yorkshire to Ellen Willmott's garden, Warley Place, in Essex, a distance of over 200 miles.[76] The local bedrock is Bagshot Formation – sand. They also brought more than 7,000 tons of rock from Yorkshire to Friar Park in Oxfordshire.[77]

Figure 43. Aysgarth rock garden built by Backhouse – limestone.

A few owners with good contacts sought rockwork supplies from abroad. Alexander Pope was one such person, he included 'a fine piece of gold ore from Peruvian mines' and 'several pieces of the eruptions from Mount Vesuvius' amongst his grotto materials, while the rockwork at Chelsea Physic Garden included volcanic stone from Mount Hecla in Iceland.[78]

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[76] Anon, 'Ellen Ann Willmott – a true genius of the place'. www.parksandgardens.org/people/493 [accessed 08/09/2017].
[77] Anon, 'Friar Park Rock Garden', *The Gardener's Magazine* (1911), p. 641.
[78] Richardson, *The Arcadian* Friends, p. 200; Historic England, 'Rockery to centre of Chelsea Physic Garden, listing 1265508, 1985.

How were rocks transported from the identified source to the construction site? An 1845 article about a London rock garden described the options:

> It is a compound of substratum of chalk, brought from Croydon by the railway and large fragments of Plymouth limestone brought in ballast to the London Docks .. then there are cart-loads of brown slag from the brick-kilns.[79]

The three key transport routes available were – by water (sea, river or canal from 1760), by road or track using wagons or carts or by some form of railway.

The water route was used at identified sites until mid-19C. These sites were all adjacent to a navigable river. When Pope requested materials from Ralph Allen's mines outside Bath they were 'put into baskets, shipped overland and by sea.' The route would have been via the River Avon from Bath to Bristol, from Bristol to London by sea and then by boat up the River Thames to be unloaded at this riverside garden. His minerals from aboard would also have come via the port of London and up the Thames. The same route was used for the Icelandic lava rock at Chelsea Physic Garden. Joseph Banks's ship, the *Sir Lawrence*, sailed up the Thames and dropped off the lava, which had been used for ballast, at Chelsea.[80]

By the 19C a comprehensive network of canals was available and used at Hewell Grange in Worcestershire. Materials were brought along the Worcester and Birmingham Canal. Later at Syon Park, granite was imported from Devon or Cornwall by sea, again using the River Thames for the last part of the journey.[81] In 1862 in an article

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[79] P.P., 'Fancy rock work', *The Gardeners' Chronicle and Agricultural Gazette* (1845), p. 592.

[80] Willson, *Pope's Grotto*, p. 21; Rebecca Dunbar, 'Leaving no rock or stone unturned', *The Telegraph* (18/08/2001), p. 33.

[81] Timothy Mowl, *Historic Gardens of Worcestershire* (Stroud, 2006), p. 179; Charles M'Intosh, *The Flower Garden* (London, 1838), p. 24.

about the rockwork at Elvaston near Derby, Robson wrote ‘I am told the floating down the river Derwent of the large stones used at Elvaston was a long and laborious job’.[82]

There are numerous references to using wagons to transport stone in both the 18C and the 19C. At Virginia Water in Surrey stone had to be brought by road for nearly 8 miles. There was great difficulty finding carriages with strong enough axles to convey the weight, but a minute of 1788 noted ‘it was found that none bore the strain as well as green alder neatly cut’.[83] The roads to Coleorton Hall in Leicestershire were bad even in the early 1800s, described as ‘heavy sand and difficult to get through’. One very large stone brought to the garden in 1818 was reputed to have taken 23 horses to get it there.[84] Even when distances were not large, materials were carted, as at Cragside where stones were transported from the quarries on the estate along temporary roads by cart. Remains of a mechanised stone cutter and crane (essential for getting the rocks onto the cart or wagon) have been found at one of the quarries (Figure 44).[85] At Aysgarth, Yorkshire, rocks were brought to site in the early 20C using a ‘stone wagon’, a long narrow low-slung cart with 4 wheels provided by the quarry. They were then unloaded by crane.[86]

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[82] J. Robson, ‘The rockery and its formation’, *Journal of Horticulture, Cottage Gardener and Country Gentleman*, Vol 2 (1862), p. 103.
[83] Virginia Water Community Website, <https://www.virginiawater.org.uk/scr/histlist.php?locid=&bid=11> [accessed 04/09/18].
[84] Anon, ‘Coleorton Hall Leicestershire – chronology of landscape development’. <www.clinchem.org.uk/coleorton/coleorton_hall_chronology.doc> [accessed 03/01/2018].
[85] Caroline Hardie and Penny Middleton, *Historic Environment Survey for the National Trust Properties in Northumberland: Cragside Estate* (Swindon, 2010), p. 81.
[86] Anderson, *Aysgarth*, p. 40.

Figure 44. Remains of a stone cutter and crane base at quarry at Cragside.

The most diverse mode of transport were the different types of railway. As early as 1734, Ralph Allen of Prior Park, Bath, formed a branch line from his early railway (tramway) running down to the River Avon from his quarries. The branch line comprised a self-acting incline with a descending loaded wagon drawing up an empty one. It was used to transport stone for the rockwork and sham bridge in his garden.[87] A hundred years later at Biddulph Grange in Staffordshire, stone from the quarry at Troughstone Hill was brought down the 'straight stone-surfaced track of even gradient' in trucks which would have been part of the quarry's early railway system.[88] In 1877 the sandstone required for the recently re-discovered Pulham rock garden at St Albans Court near Dover came by train from Maidstone to Adisham which was the nearest station to the garden. From there it was taken the last three miles by horse and cart. This form of transport was remembered by local people because 'old fashioned'

[87] Maggs, *Steam Trains*, p. 8.

[88] Hayden, Peter, *Biddulph Grange Staffordshire: a Victorian garden rediscovered* (London, 1989), p. 96.

horses were used rather than agricultural traction engines they were used to seeing.[89] (Traction engines had been used in agriculture since mid-1800s.)

Suppliers and contractors also made regular use of the growing rail network from the 1850s onward (Figure 45). In 1870 plants for Brodsworth Hall coming from James Veitch's nursery cost £2 19s 6d for 'carriage on the railway'.[90] James Backhouse & Son sent plants and rocks from their nursery site near York all round the country. William Barron & Son used the rail network to transport trees, men and equipment to customers' sites, while James Pulham & Son used railways to transport men and materials.[91] It was usual practice to order the stone well before work was due to start because of the uncertainly of using connecting transport routes.[92]

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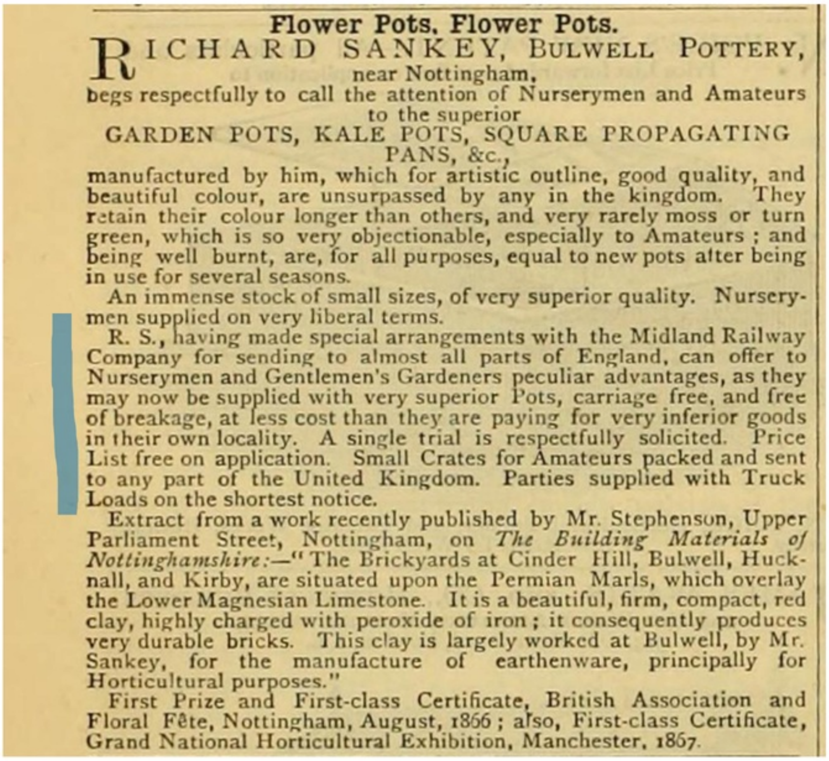
[89] Peter Hobbs, 'A Pulham garden rediscovered in Nonington, Kent', *Archaeologica Cantiana*, Vol 138 (2017), p. 294.

[90] Gillian Mawrey and Linden Groves, *The gardens of English Heritage* (London, 2010), p. 147.

[91] Elliott, *Victorian gardens*, p. 16; University of York Borthwick Catalogue, 'Backhouse Plant Nursery, York'. <https://borthcat.york.ac.uk/index.php/backhouse-plant-nursery-plant-nursery-york> [accessed 08/09/18]; Paul Elliott, Charles Watkins & Stephen Daniels, 'William Barron (1805-91) and nineteenth-century British arboriculture', *Garden History*, 35 Supplement (2007), p. 140

[92] Elliott, 'The British rock garden', p. 4.



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An immense stock of small sizes, of very superior quality. Nurserymen supplied on very liberal terms.

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Extract from a work recently published by Mr. Stephenson, Upper Parliament Street, Nottingham, on *The Building Materials of Nottinghamshire*:—"The Brickyards at Cinder Hill, Bulwell, Hucknall, and Kirby, are situated upon the Permian Marls, which overlay the Lower Magnesian Limestone. It is a beautiful, firm, compact, red clay, highly charged with peroxide of iron; it consequently produces very durable bricks. This clay is largely worked at Bulwell, by Mr. Sankey, for the manufacture of earthenware, principally for Horticultural purposes."

First Prize and First-class Certificate, British Association and Floral Fête, Nottingham, August, 1866; also, First-class Certificate, Grand National Horticultural Exhibition, Manchester, 1867.

Figure 45. Advertisement for goods transported by train, 1873.

Surveying and setting out.

Before a design was made, a surveyor would be brought in to chart the topography of the land. Distances would be measured so that a ground plan could be produced, and the site marked out. Testing the soil with a wooden probe was often undertaken in order to ascertain the nature of the sub-soil – important for designing foundations and excavations. Bore holes were made at Lodge Park, Gloucestershire in 1731 'in order to try how ye clay lay in order to find whether Mr Bridgeman's lake be feasible there'.[93] After the survey and soil testing the ground would be laid out with wooden pegs to identify exactly where construction elements were to be placed.[94]

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[93] Nicky Smith, 'Lodge Park and Charles Bridgeman, Master of 'Incomprehensive Vastness'', *Garden History*, 34.2 (2006), p. 241.

[94] F. W. Meyer, *Rock and water gardens* (London, 1910), p. 8.

Designs/plans

In the 18C, when you wanted a house built you would appoint an architect. They would produce scaled plans and cross-sections, together with more detailed drawings for features such as roofs, windows and chimneys. In addition, a scale model might be produced such as the one the Duke of Portland required at Welbeck Abbey where 'a flaw or any aspect of inelegance was detected by him at once'.[95] Was the process the same for designing a rockwork feature in the garden?

There are very few existing original plans for rockwork features in either the 18C or 19C, and those that exist do not contain sufficient detail for a building contractor to follow. The original Pulham plan for St Fagans from 1873 is held at Glamorgan Archives in Cardiff (Figure 46). However, it is more a schematic layout plan than a detailed plan of how the rockwork and water management system should be put together.[96] Other contemporary drawings or paintings by owners or architect designers include a 1766 plan for Oatlands grotto, a scaled plan by Hamilton for the grotto at Bowood and Wordsworth's plan and description of the winter garden at Coleorton Hall, contained in a letter to Lady Beaumont (Figures 47, 48).[97]

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[95] Leonard Jacks, *The great houses of Nottinghamshire, and the county families* (Nottingham, 1881), p. 161.

[96] Glamorgan Archives (GA), DPL/943/1, *Plan of proposed improvements to the gardens at St Fagans castle by James Pulham or Broxbourne and Broxton*, 1873.

[97] Symes, 'New light on Oatlands Park', p. 145; Symes, 'Charles Hamilton at Bowood', p. 217; The Morgan Library and Museum, New York, 119205, William Wordsworth, *Plan for a winter garden at Coleorton Hall*, 2008.364.

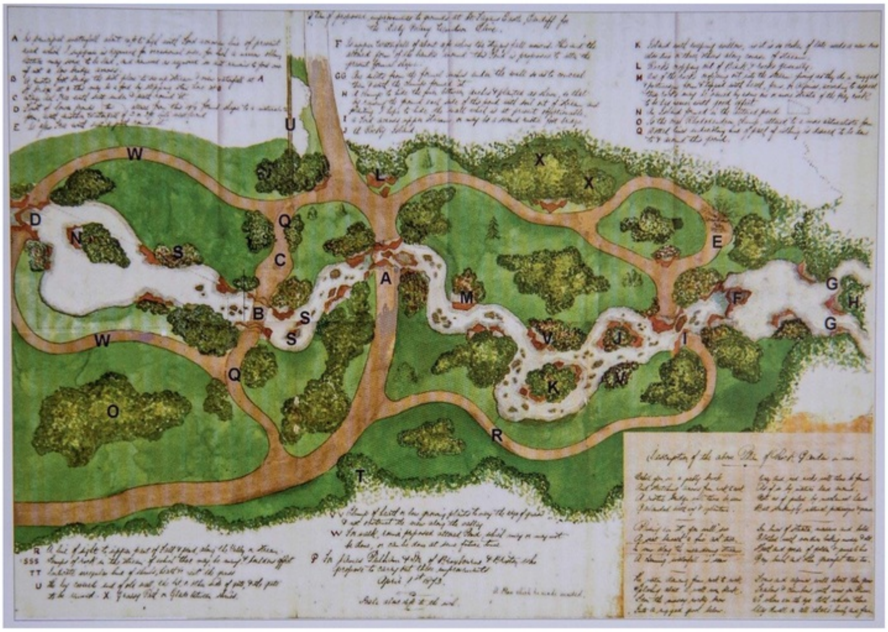

Figure 46. James, Pulham, ink and watercolour plan for the rock garden at St Fagans, 1873.

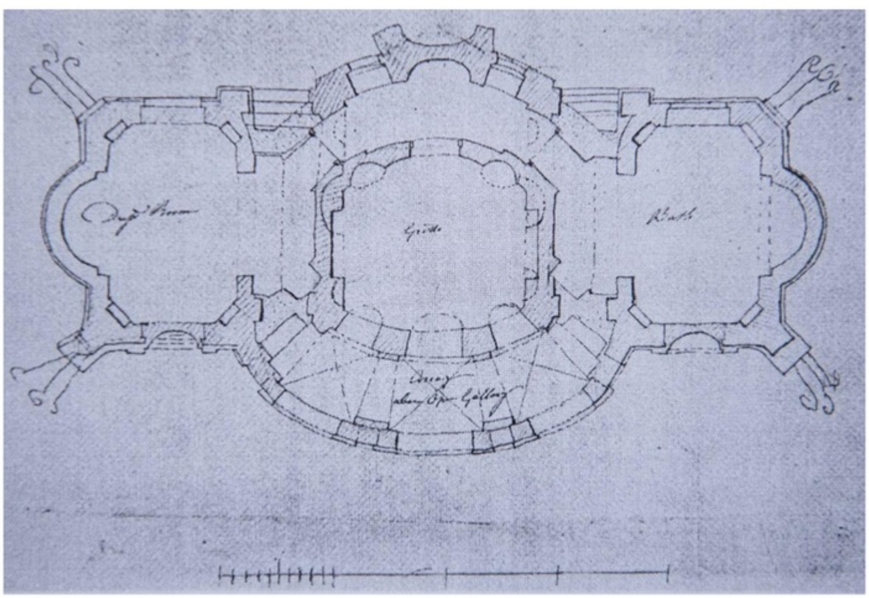

Figure 47. Plan of Lord Lincoln's grotto, 1766.

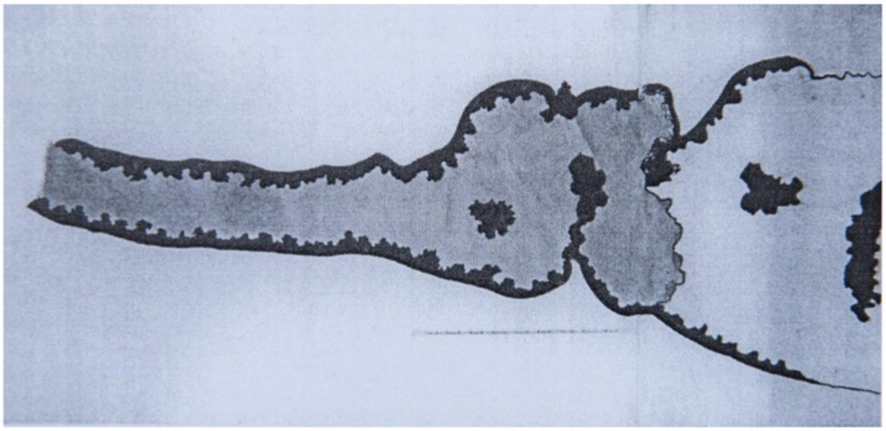

Figure 48. Charles Hamilton, *Scale plan of the grotto at Bowood*, Wiltshire, c1781.

Thomas Sandby designed the replacement rockwork and grotto at Virginia Water, producing a series of pen and watercolour paintings which would have given the builders some idea of the rock placements (Figure 49).

Figure 49. Thomas Sandby, *Design for rock-work and cascades at Virginia Water, Windsor Great Park*, 1780s.

All the drawings or paintings noted so far left out details of construction. Were there any including that detail? One example from a Swedish visitor in the 1780s did. Frederik Magnus Pyper (often spelt Piper) was a landscape architect who had training in hydraulics and engineering. He made detailed plans and cross-sectional drawings at Painshill and Stourhead from which you could deduce aspects of construction methodologies, materials used and water management systems (Figures 50-52).[98] The drawings and notes could have been used to replicate the rockwork features elsewhere.

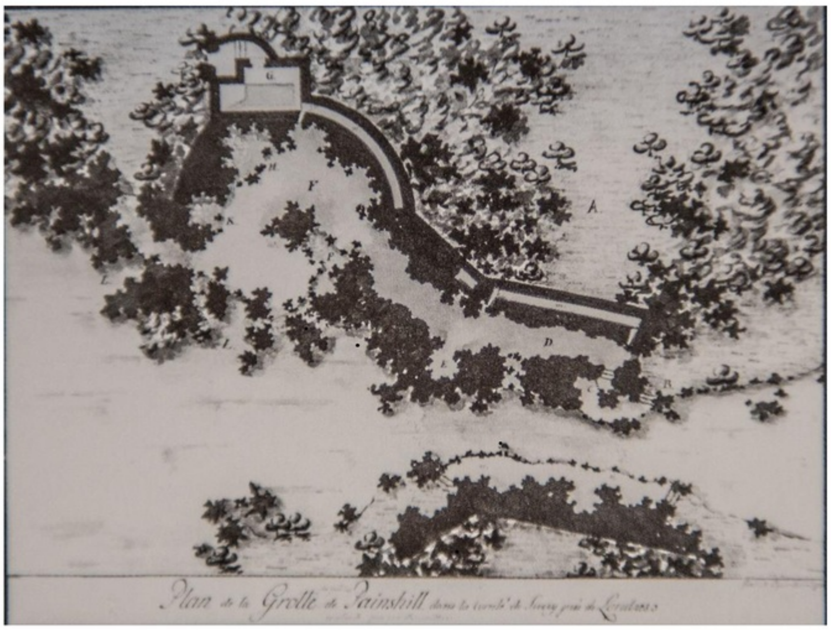

Figure 50. Pyper's plan of the grotto at Painshill, showing pump house at letter G.

[98] Symes, *Mr Hamilton's Elysium*, p. 99; Kenneth Woodbridge, *The Stourbridge Landscape* (London, 1996), pp. 47-8.

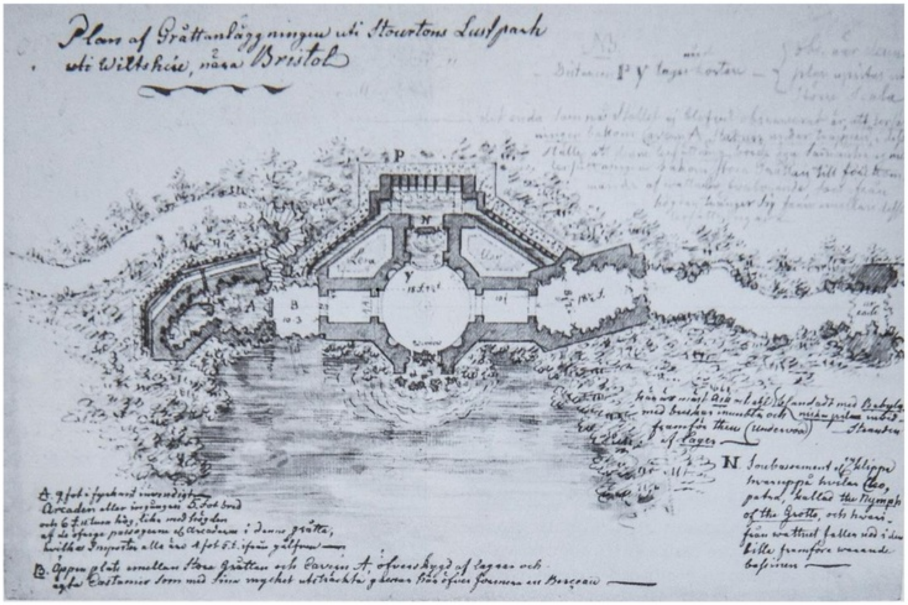

Figure 51. Pyper's plan of the grotto at Stourhead with dimensions and key.

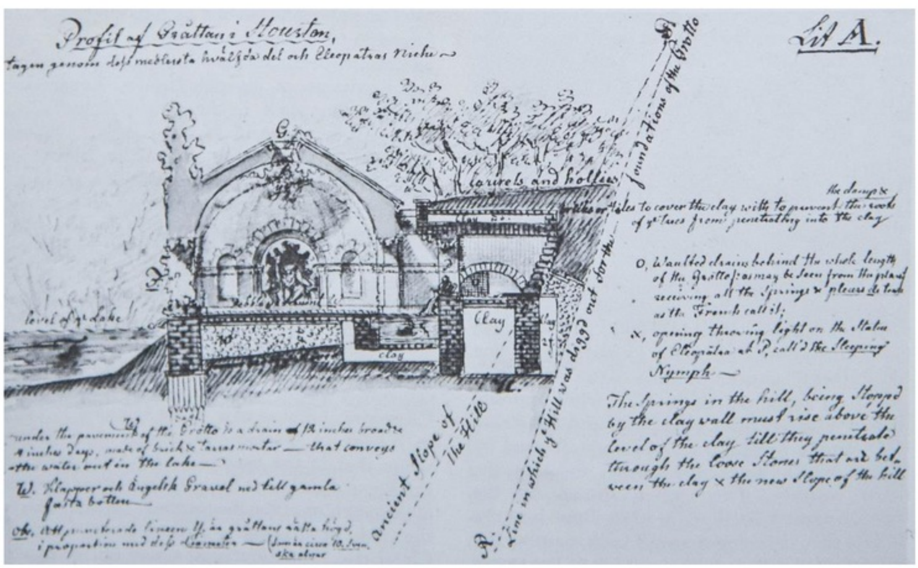

Figure 52. Pyper's cross-section of grotto at Stourhead showing excavation line, materials and levels.

An alternative approach noted on several sites was to use three-dimensional models. Symes found evidence suggesting a 'model in wood' was made for the grotto at Oatlands. This would have been a useful aid to the workmen employed there.[99] At Stourhead, in a letter dated 1765 Hoare writes, ‘Messrs Bampfield and Hoare (i.e. William Hoare of Bath) have made an ingenious model for the cascade’.[100] The letter was written before the cascade was built so the model could have acted as a construction aid.

In the following century at Hoole House, the home of Lady Broughton, Loudon writes that ‘the design of the rockwork was taken from a small model representing the mountains of Savoy’.[101] Could this have been a real 3-dimensional model to assist the construction? Edward Cooke’s diary entries from 1849 onwards are studded with references to making designs and plans. While at Biddulph he makes reference to ‘modelled rockwork in clay’, ‘Mr B and I made model of fern recess’ and ‘made models with carpenter of different things’.[102] For irregular rockwork structures a 3-dimensional model would have been a valuable aid when placing rocks in position.

Without detailed construction plans, workmen would have taken a trial and error approach, then checked the final result by eye. An example of this occurred at Friar Park where the rocky area near the Matterhorn required several attempts to get it ‘right’. The layout of the individual rocks was remodelled four times. After the third attempt the rocks were removed and, according to Crisp, was only at last got into its present position by ‘substituting boxes covered with matting which could be shifted into various positions until a satisfactory arrangement was obtained’.[103] Here is an example of using a dynamic modelling technique.

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[99] Michael Symes, ‘New light on Oatlands Park’, p. 146.
[100] Woodbridge, *The Stourbridge Landscape*, p. 56.
[101] Loudon, ‘Hoole House’, p. 357.
[102] RHS Lindley Library, 54053000441505, ‘E. W. Cooke at Biddulph Grange: from transcripts of his diaries, original of which are at the National Maritime Museum, Greenwich’, unpublished typescript, 1836-1872.
[103] Frank Crisp, *Friar Park, Henley on Thames*: *Guide for the use of visitors* (place of publication not identified, 1910), p. 77.

These exemplars indicate that whilst very few original design plans exist with enough detail to aid the construction process, there were alternative approaches using paintings and models to give a 3-dimensional effect which could have been easily understood by labourers working on site.

Excavation

The next stage in constructing a rockwork feature was always excavation to level the site or to make hollows for water or rock. Throughout the 200-year period of this research, this was done by hand using a pickaxe, shovel and wheelbarrow or basket to remove the spoil. The scale of earth moving was substantial, on a par with large civil engineering works.[104] In one part of Stowe, over 23,000 cubic yards of earth were removed requiring 9,400 man-days and 225,000 barrow loads. A hundred years later 150 labourers moved 6,000 tons of earth to create Ten Foot Pond at Sheffield Park. At Waddesdon an entire hilltop was removed in the 1880s – an average of 12 feet of soil from 10.5 acres, equating to over 200,000 cubic yards (Figure 53).[105] Comparing these statistics with Loudon's advised rate of hand excavation for one labourer of 10 cubic yards in a day on soft ground, plus another labourer to move the excavated material, it would have required 100 men, half digging and the other half removing the spoil, 400 working days to complete.[106] It is no coincidence that the majority of Brown's commissions were south and east of the Tees-Exe line where the underlying rocks were softer and easier to work by hand.[107]

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[104] Barry Goldsmith Clarke et al., 'Engineering the landscape – Capability Brown's role', *Proceedings of the Institution of Civil Engineers – Engineering and Heritage*, Vol 170.1 (2017), p. 21.

[105] Hinde, Thomas, *Capability Brown: the story of a master gardener* (London, 1987), p. 27; Annie Bullen, *Sheffield Park and Garden* (Swindon, 2017), p. 31; Roderick Floud, 'Manging and running great gardens 1700-1900', Gresham Lecture, 20/06/2013.

[106] John Claudius Loudon, *An Encyclopaedia of Gardening* (London, 1826), p. 378.

[107] Clarke et al., 'Engineering the landscape', p. 22.

Figure 53. Excavation work at Waddesdon.
Note the horse and cart, tramway and use of pick-axes and shovels.

Spoil from these excavations were used in a variety of ways, usually nearby as removing them completely would have been extremely expensive and labour intensive. At Scott's grotto in Hertfordshire, the chalk spoil from the grotto excavation was used to lay down part of the Ware to Hertford Road. Sixty years later at Pencarrow and Elvaston the spoil was used to create mounds or embankments for rockwork, those at Elvaston were 50-feet tall in places. In the 1880s soil from the excavations for the sunken rock garden at Kew was 'thrown from the bottom to the sides' in order to gain the necessary depth with as little labour as possible.[108]

Foundations

Foundations, a necessary component of any construction, were rarely written about unless something went wrong. Work on constructing foundations for the house at Waddesdon Manor was

[108] Historic England, 'Scott's Grotto', listing 1238171, 1950; W.E.R., 'Gardening Memoranda', *Gardeners' Chronicle* (1842), p. 560; Elliott, 'William Barron (1805-91), p. 133; W. J., Bean, *The Royal Botanic Gardens Kew* (London, 1908), p. 210.

fraught with problems. Baron Rothschild narrated the story in his Red Book. The part of the hill selected for the site consisted of sand and the foundations once completed gave way suddenly. The whole of the brickwork required removal and 30ft of sand excavated until a firm bottom of clay was reached. His comment was 'I now began to realise the importance of the task I had undertaken'.[109]

Building the core

Once foundations were in place, brickwork or pieces of stone could be placed and fixed. The construction of nearly all grottoes both above and below ground involved a core of brickwork, over which a layer of rockwork decoration was added both inside and out. Alexander Pope's tunnel, part of his grotto complex, was arched with smooth-facing brick. The precision of the brickwork where the arches intersect, together with the high quality of pointing to the walls led Willson to suggest that it was initially intended to be self-finished, with the ornamentation coming later.[110] Similar descriptions of a mortared-brick core structure exist for Painshill, Ascot Place and Waddesdon grottoes.[111]

Tunnels to and from grottoes were generally made by the 'cut and cover' technique i.e. the whole area was excavated, a brick and mortar core was built inside the excavated area and then the top was covered back with soil and turf. The 1881 description of the many miles of tunnels at Welbeck Abbey by Leonard Jacks provided the detail:

> The tunnels are built of brick with a covering of hard plaster. The light is admitted from above through circles of

[109] Baron Ferdinand Rothschild, 'The Red Book', 1897. <https://issuu.com/waddesdonmanor/docs/red_book_single_page> [accessed 04/09/17].
[110] Anthony Beckles Willson, 'Alexander Pope's Grotto in Twickenham', *Garden History*, 26.1 (1998), p. 35.
[111] Symes, *Mr Hamilton's Elysium*, p. 97; Andrea Walker, 'Ascot Place restoration''; Hitching, *Rock Landscapes*, p. 110.

plate glass, which are placed in round frames. Appearing at intervals among the grass of the park these circular arrangements would puzzle any person who was not in the secret.[112]

The tops of these tunnels were only a foot or two underground allowing these 'light-wells' to be incorporated.

Another technique borrowed from an allied industry was the 'pillar and stall' method used in underground quarrying and mining. Pope used this method when extending his grotto in his house basement. In 1740 he wrote to his friend, Dr William Borlase, 'I have opened the whole into one room, groin'd above from pillar to pillar (not of a regular architecture but like supporters left in a quarry)'. He would have seen this technique used by another friend, Ralph Allen at his Combe Down quarries near Bath.[113] Another example was the grotto at Hawkstone, hewn out of solid rock, where columns of stone were left to support the roof (Figure 54).[114]

Figure 54. Hawkstone Park grotto 2017 – showing pillar and stall construction. Compare with Figure 23 in Chapter 3.

[112] Jacks, *Great Houses of Nottinghamshire*, p. 165.
[113] Willson, *Alexander Pope's Grotto*, p. 17.
[114] Historic England, 'Hawkstone', listing 1000199, 1986.

How were roofs and ceilings constructed? Some grottoes built above ground had timber beams supported off one or more columns or walls, which were then clad with lead or slate, making a flat roof as at Painshill.[115] Inside, the ceilings were vaulted either a simple barrel vault as at Warmley and Enville or the more complex groin vault like the one built for Pope at Twickenham (Figure 55).[116] Both designs and construction methods had been used for centuries in churches and cathedrals.

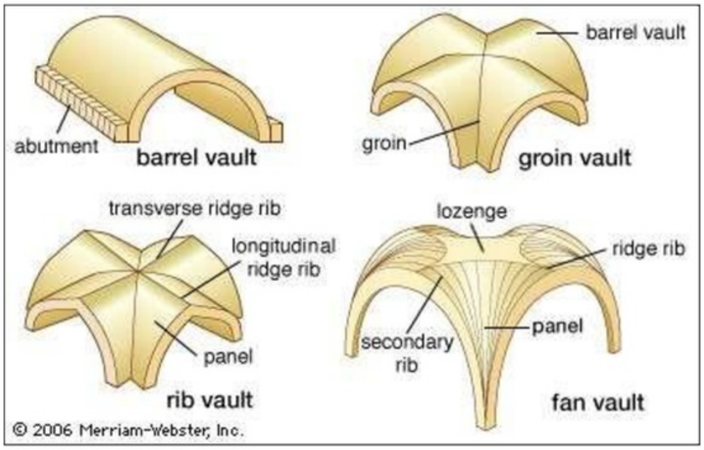

Figure 55. The difference between barrel and groin vaulting.

A different approach was taken for the grotto at Oatlands, built around the same time as Painshill. It had an unusual 2-story construction, built against a bank which avoided the need for deep foundations. The upper chamber, used for entertaining, was accessed from ramps curving up the bank. This had a pitched roof with glazed windows (Figure 56).[117]

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[115] Symes, *Mr Hamilton's Elysium*, p. 99.
[116] Atkins Heritage, *Champions brassworks and gardens*; Symes and Haynes, *Enville, Hagley, The Leasowes*, p. 72.
[117] Symes, *Fairest scenes*, p. 31.

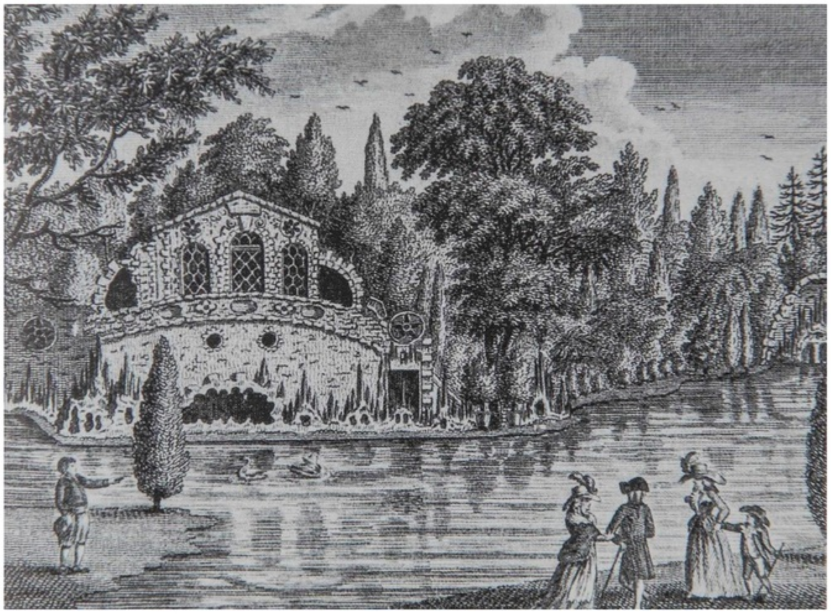

Figure 56. The grotto at Oatlands showing pitched roof and glazed windows.

By design grottoes and tunnels leading to them were intended to be dark so lighting was limited. Often there were slits or holes in the walls or lanterns set in the ceiling or niches made in the walls for candles such as those found at Warmley grotto (1746), Scotts grotto (1770) or underground rooms at Welbeck Abbey (1850s). Occasionally no lighting was provided at all, as at Hawkstone, where a trained guide led nervous visitors through the pitch-black tunnel before arriving at the grotto cavern.[118]

Any rockwork feature incorporating moving water, from a grotto with water trickling down the walls, to a cascade producing 'white water', required a planned water management system. This would comprise a water source or sources, power to move water from one place to another, a means of connecting the source to the rockwork feature and some means of controlling the water flow and/or turning it on and off. Rockwork features needed their water management systems 'built in' before the feature was finally decorated or finished, in a similar way to a domestic house today where central heating or

[118] Jackson, *Shell houses and grottoes*, p. 19

electrical systems are put in place before plasterwork and decoration is added. In this way pipes, taps or sluices could be embedded within walls, ceilings or dams and not be visible when the final structure was complete, making it appear that water was flowing naturally through or over the rockwork feature. Whatever their size and complexity, they all needed the same components which will be considered in turn.

Most sites sourced their water from a well, natural springs, leats, brooks or rivers. In most cases sources were blocked or dammed to form an impounded pond or lake (for further details see Appendix 1, Table 5). This then acted as the head of water to service the water features. Two exceptions to this were Goldney and Painshill both created in the first half of the 18C. At Goldney the water source was a well from which water was pumped to supply the grotto, using an early Newcomen steam engine. The supply for the lake at Painshill was the River Mole which was 15ft lower than the site. Hamilton is credited with designing the first pumping machine, a 26-foot diameter vertical water wheel (Figure 57). The water ran from the river to the waterwheel and from there in pipes to the cascade at the head of the lake, replenishing the lake and returning to the river at the far end of the lake. Water for the grotto was raised from the lake into a sump underneath the floor, pumped up to ceiling level and then dripped down the walls to a pool in the floor and from there back to the lake.[119]

[119] Symes, *Mr Hamilton's* Elysium, pp. 70-74.

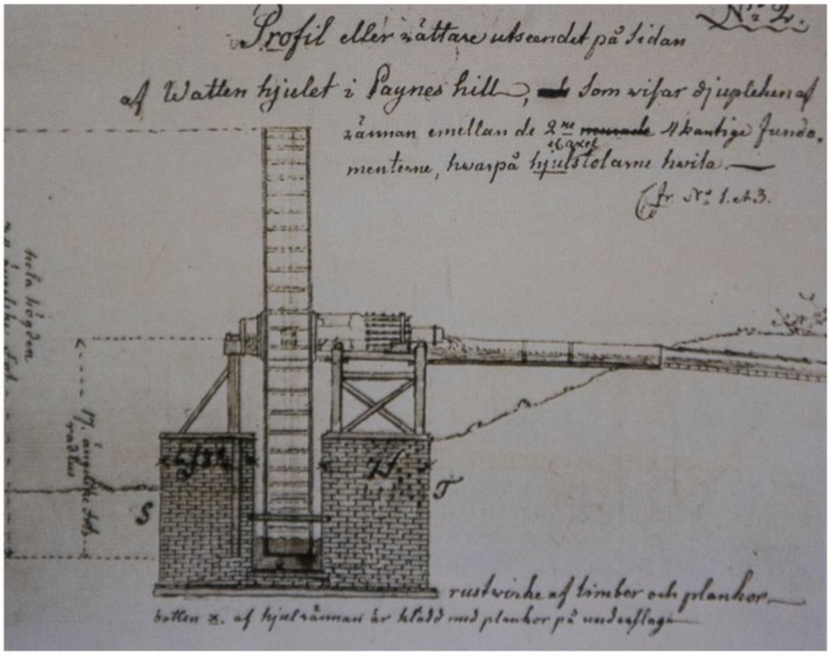

Figure 57. Pyper drawing of water wheel at Painshill.

In the 19C, on smaller sites, an alternative to a lake was a water tower, used for storage and to provide a head of water. Examples were built at Hewell Grange (late 1800s addition) and The Dell (1888). The tower at Hewell Grange was built to power hydraulic lifts in the new home for Lord Windsor-Clive but at The Dell, James Pulham rendered the outside and made it look like a crenelated medieval tower (Figure 58). The water was used for the stream and pool in the rock garden.[120]

[120] Historic England, 'Water Tower about 300m south of Hewell Grange', listing 1296648, 1986; Hitching, *Rock landscapes*, p. 138.

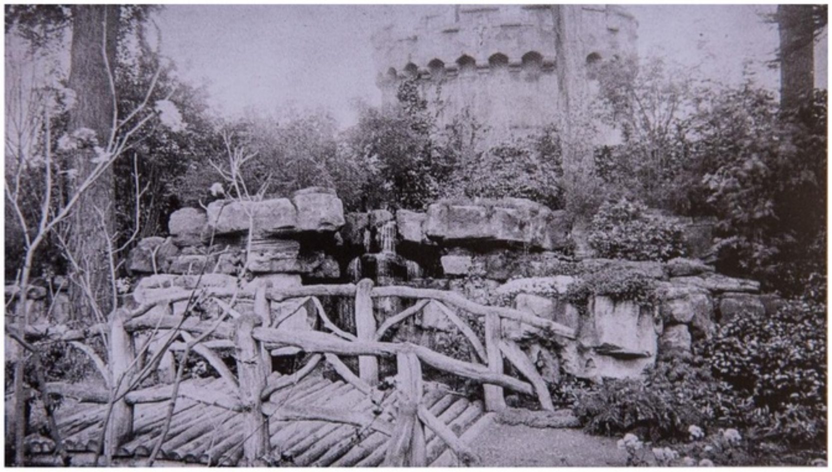

Figure 58. Pulham's water tower at The Dell.

Alternative approaches had to be considered where there was no natural water source. From 1880 mains water was supplied for the house and gardens at Waddesdon Manor by Chiltern Spring Water Company, which members of the Rothschild family had helped to establish. It required 7 miles of pipework to reach the site, plus several large storage tanks in the grounds.[121]

The simplest source of power to move water was gravity. If you had a hilly site and a plentiful supply of water, your water features could operate continuously by gravity with no need for pumps, re-circulation or storage facilities. One such site was Pope's grotto at Twickenham. Whilst building the tunnel under the road he discovered a spring. The tunnel sloped downwards from the garden, the gradient following the natural fall of the land from his garden, through the tunnel and basement, towards the river. Hence gravity provided the power for the water flow through the grotto.[122]

Other sites needed to pump water from one place to another using a variety of different power sources, from wind, water, animal or

[121] Palmer and West, *Technology in the country house*, p. 54; Rothschild, *The Red Book*, 1897.
[122] Willson, 'Pope's grotto', p. 35.

human, steam, hydraulic pressure, or combustion engine. In William Champion's gardens in Warmley near Bristol (1746), an early example of industrial picturesque style, he used water wheels, an industrial windmill, a horse mill, and a 48-inch diameter Newcomen steam engine to move water around the site and to recycle it back to the lake (Figure 59). It is possible he channelled steam from the Newcomen engine to the grotto for a dramatic effect.[123]

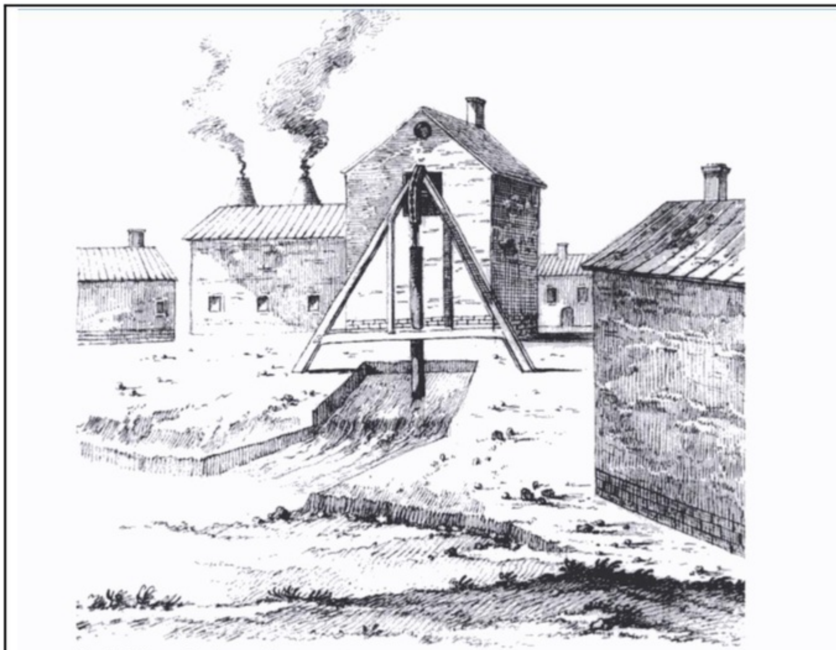
Fig. 142 Fire-engine house and water pump

Figure 59: Sketch of the steam engine at Warmley by Reinhold Angerstein in 1754.

Over a hundred years later Battersea Park and Kew Gardens both used steam engines to pump water, the one at Kew having replaced an earlier 18C horse-driven pump, while hydraulic rams were used at Sheffield Park and Gatton Park (Figure 60).[124]

[123] Atkins Heritage, *Champions brassworks*, pp. 19-20.
[124] Historic England, 'Battersea Park', Listing 1000283, 1987; Bean, *Kew*, p. 51; Hitching, *Rock landscapes*, p. 125; visitor's display board, Gatton Park, photographed 2017.

Figure 60. Hydraulic ram pump used in a garden in Derbyshire.

The most extensive and complex water management system was developed at Cragside in the 1870s by William Armstrong, the hydraulic expert. His system employed hydraulic rams to pump spring water, the head of water provided by the lakes to drive a range of hydraulic machinery in the house, and to drive a turbine and a DC generator. The cascade ran via gravity and water was put to successive uses both utilitarian and decorative.[125]

On large estates it was not uncommon to find the water management system serving more than one purpose. Francis Wright had a dual-purpose water management system at Osmaston Manor (1846). The iron waterwheel drove two water pumps (Figure 61). One moved water from a spring to a reservoir above the house for domestic use and the other lifted water from the river to another reservoir which fed

[125] National Trust, *Cragside Northumberland* (London, 1997), p. 29; Archaeo-Environment Ltd., *Historic Environment Survey for the National Trust properties in Northumberland: Cragside Estate* (Barnard Castle, 2010), p. 97; Irlam, Geoffrey, *Domestic Engineering at Cragside* (Swindon, 1989), pp. 15-18.

the hydraulic lifts in the house and supplied the garden features. The waterwheel also powered a sawmill.[126]

Figure 61. Pump house at Osmaston Manor. The cascade is on the left.

A range of mechanisms for connecting the source of water to the rockwork feature have been identified, including ditches, stone conduits, culverts, wooden flumes and various types of pipe (see Appendix 1, Table 5). Many sites used a combination of these mechanisms to get water to and from the rockwork feature. In the first half of the 18C at Prior Park near Bath, there was an unusual cascade from the Serpentine Lake which disappeared under the Grass Cabinet (Figure 62). Visitors would have been able to stand right at the foot of the cascade on the grass. To achieve this effect water was fed through pipes from nearby springs into the lake and was then controlled by a sluice and flowed through a wooden pipe under pressure to the cascade. At the bottom of the cascade water flowed into a pipe under the Cabinet and reappeared in front of the

[126] Ian West, 'The world's most technologically advanced house in 1850?', *Historic England Research*, Issue 4 (Winter 2016-17), p. 35.

Gothic Temple and then joined an elaborate system of culverts taking the water underground to the upper lake (Figure 63).[127]

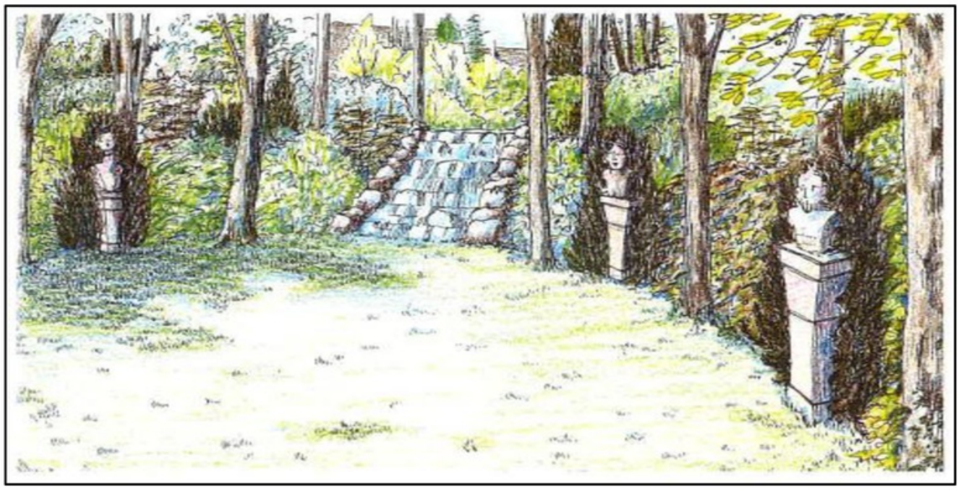

Figure 62. Prior Park cascade from Serpentine Lane to the Cabinet.

Figure 63. Prior Park – stone culvert found during restoration of the cascade.

At Dewstow, a Pulham construction of underground grottos and water gardens, started in 1895, there was no natural water source. All the water features above and below ground were supplied by

[127] Matthew Ward, *Prior Park Landscape Garden: Conservation Plan 2002* (Swindon, 2002), pp.23-4; Matthew Ward, *Prior Park Landscape Garden* (Swindon, 2009), p. 10; Secrets of the Stately Garden, Time Team Special 28 (2007) <https://www.youtube.com/watch?v=B6eW_EIHXQI > [accessed 12/01/2018].

mains water held in a large water tank. The water was pumped round the system by a combustion engine housed in the pumphouse which was disguised by a rockwork façade. There was extensive use of piping, rills, aqueducts, exit pipes, standpipes and water-cocks, some of which were hidden in niches in the grotto, for circulating the water and for turning features on and off. Any overflow was taken away by carefully made grooves in the Pulhamite floors (Figure 64).[128]

Figure 64. Pulhamite floor in underground grotto at Dewstow.

One constraint on moving water any distance was the availability of pipes. In the 18C lead pipes were too expensive for anything more than short lengths so most water pipes were made of wood which had a limited life.[129] This is confirmed by evidence from the database. Wooden pipes, often elm, made by hollowing out tree trunks, were used at Prior Park (1734) to feed the cascade, at Hackfall (1749) to

[128] CADW Parks & Gardens Register, 'Dewstow House, Garden, Caldicot', NPRN 266053. <http://www.coflein.gov.uk/site/266053/details/dewstow-house-garden-caldicot> [accessed 12/12/17]; Anna Pavord, 'Elaborate 19th-century grotto uncovered in a Gwent garden', *The Independent* (28/03/2009), p. 25; Hitching, *Rock landscapes*, p. 166.

[129] Palmer and West, *Technology in the Country House*, p. 47; Emergency Plumber UK, 'Pipes – a brief history in England'. <https://www.emergencyplumber.uk.com/plumbing/the-history-of-pipes > [accessed 02/01/2019].

feed the Fountain in Fountain Pond and at Croome Court (1760) to feed water from the pool to the grotto.[130]

In contrast, short lengths of lead piping were found in the walls of the grotto at Oatlands (1762) and at the cascade at Thoresby (1791) where ‘the water has been so constructed by concealing leaden pipes that it appears to have forced its way through the ledges of the rocks’.[131] By the beginning of the 19C cast-iron pipes were available and were used by Francis Wright, owner of the Butterley Iron Works, at his estate, Osmaston Manor, in 1849.[132] Also in use in the latter part of the 19C were underground ceramic pipes at Cragside, Northumberland and at Sheffield Park, Sussex where water was pumped through a 27” diameter earthenware pipe to the Storage Pond.[133]

The flow of water to a cascade was controlled by a sluice or a tap depending on the volume and pressure of water involved. During the 19C there was an evolution of sluice gate construction found at Sheffield Park in Sussex. In 1997 the Stone Bridge, which is adjacent to the Great Cascade built by James Pulham & Son, was the subject of a detailed engineering survey prior to reconstruction. A cast iron sluice gate was found, dating to 1883/4, which was constructed in a very different way from earlier models. It had a moving gate – lift to open and lower to close but this sluice gate sloped at 25^{o} from the vertical and opened by rotating using a quadrant rack at each end (Figure 65).[134]

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[130] Harrogate Borough Council, *Hackfall: conservation area character appraisal* (Harrogate, 2011), p. 10; Anon, ‘Croome Park Grotto’.

[131] Anthony Greenstreet, ‘A lost grotto’. <https://www.essentialsurrey.co.uk/home-property/a-lost-grotto-oatlands-park-history > [accessed 29/01/2018]; John Claudius Loudon, *Observations on the theory and practice of landscape gardening* (London, 1803), p. 37.

[132] Alison Haslam, ‘Osmaston Manor House’, *Derbyshire Archaeological Society Newsletter*, 76 (2013), p. 12.

[133] Hardie and Middleton, *Cragside Estate*, p. 81; Ron Martin, ‘Sheffield Rock Garden – stone bridge and sluice’, *Sussex Industrial History*, Vol 27 (1997), p. 2.

[134] Martin, ‘Sheffield Rock Garden’, p. 3.

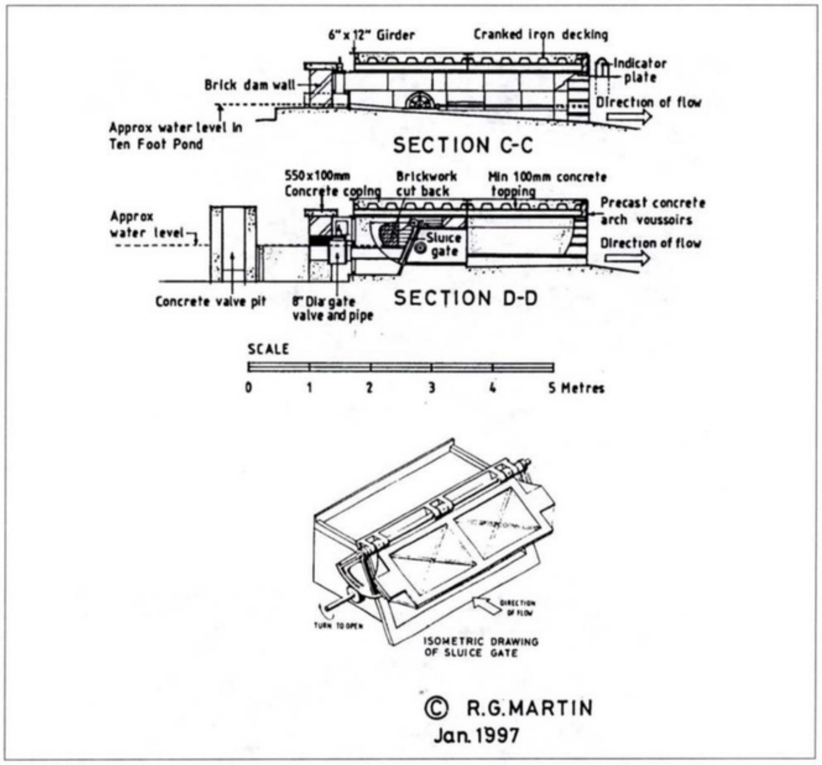

Figure 65. Sheffield Park – 19C sluice design from engineering survey.

Not long before, Stoney had invented the rolling sluice, with a similar action, which was used in the development of the Manchester Ship Canal. This sluice construction is very similar to today's Thames Barrier which also uses radial gates.[135]

Taps required valves to control the pressure. Where there was very high pressure a complex design using internal valves was required. Where there was no great pressure a simpler tap would do such as the one at the top of the cascade at Cragside in Northumberland which runs from the house down to Debdon burn below or the one observed at Wotton House (Figure 66).[136]

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[135]Grace's Guide, 'F.G.Moroney-Stoney'. <https://www.gracesguide.co.uk/Francis_Goold_Morony-Stoney> [accessed 02/01/ 2019]; Thames Barrier <http://www.gov.uk/guidance/the-thames-barrier#how-the-thames-barrier-works> [accessed 02/01/2019].

[136] Observations during visit, 2017.

Figure 66. Simple tap at the top of the cascade at Cragside.

Where the water supply was limited, accounts were found of gardeners or servants turning cascades on and off to cater for groups of visitors. A theatrical spectacle was created at Enville. Visitors were led into the octagonal room of the Boat House within which was a painted glass window obscuring the view out. As they were admiring the interior a servant was sent running a quarter of a mile uphill to release the sluices on the holding pools. At the first sound of water the windows were slid open to reveal the cascade at its finest with water causing waves to flow across Temple Pool.[137] Over 150 years later at Gatton Park in Surrey, important visitors would have a gardener preceding them to turn on the taps that controlled the cascade and another following them to turn them off before the water in the header tank ran out.[138]

Final fix – decorations

The grotto rock *par excellence* in the 18C was spongestone, a porous limestone from the Gloucestershire region. It has the

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[137] William Marshall, *On planting and rural ornament*, (London, 1803), Vol 1, p. 328.

[138] Display board at Gatton Park showing history and restoration of Pulham pond and cascade, photographed September 2017.

appearance of honeycomb, 'pitted with round holes of varying sizes and depths as if fingers had been stuck into a lump of dough'. It has incorrectly been called 'tufa' by many contemporary commentators as well as garden historians, with the exception of Thomas and Symes.[139] Of the twelve 18C grottos where the rock used was described as 'tufa', only two sites used natural tufa, the rest used spongestone (Figure 67). In the 19C only one site, Elvaston in Derbyshire used natural tufa. William Barron wrote 'upon having a grant for a considerable portion of tufa I took advantage'. The large grotto-complex was made using a composition of crushed tufa and gritstone.[140]

In geological terms tufa is a very new material, formed by limey water in mineral springs dripping over moss and other detritus, rather like the formation of stalactites and stalagmites. It is initially soft but hardens with age. It is lightweight so is easy to handle. It is primarily found in Gloucestershire, Derbyshire and parts of Yorkshire. It was used extensively at Hackfall, for the grotto and other buildings, as it was available on site. Tufa was so prized that it was imitated by Pulham in the 19C, a good example being in the grotto/fernery at Swiss Garden.[141]

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[139] Thomas, *The rock garden*, pp. 18, 49; Symes, *Mr Hamilton's Elysium*, p. 97.
[140] William Barron, *The British Winter Garden* (London, 1852), p. 73; Jackson, *Shell Houses and grottos*, p. 39.
[141] Woodland Trust, 'Uncovering Hackfall's Heritage'. <https://www.woodlandtrust.org.uk/mediafile/100049798/ks3-and-ks4-packs.pdf > [accessed 06/01/18]; Alan Bishop & Associates, 'Restoration at Swiss Garden'. <http://www.alanbishopassociates.co.uk/casestudies.html > [accessed 05/09/18].

 

Figure 67. Tufa (left) at Hackfall and spongestone (right) at Painshill.

Table 2 shows the occurrence of key materials used to decorate grottos in the 18C and 19C. The 'sparkle' factor provided by using shells and spars, prevalent in the 18C, waned significantly during the next 100 years and the number of undecorated grottos increased.

Table 2: materials used in grotto decoration		
Feature	**No sites 18C**	**No sites 19C**
Shells	11	2
Stalactites	6	3
Spar/fluorspar	11	1
Pebble floors	9	1
Tufa inside or outside	9	6
Slag	8	1
No internal decoration	8	10
Total number of sites	25	16

A variety of spars were popular in the 18C as they reflected light and showed off geological specimens. The Countess of Coventry ordered 'Derbyshire Petrifactions', probably blue-john (a variety of fluorite), for the grotto at Croome Court. George Lyttelton requested spars and 'Kynance stone' from William Borlase in Cornwall to decorate Lady Elizabeth's grotto at Hagley in the 1750s. [142] Later, at Ascot Place, the grotto was covered in white spar throughout, interspersed with polished pebbles and petrifactions.[143]

Nearly a third of all 18C grottoes studied had no internal decoration. Those which were hewn out of solid rock remained as caves, usually with a picturesque view. Examples include Hackfall where the grotto was little more than a seat to rest and admire the views, Rokeby, where Scott's grotto/cave was cut out of the limestone cliffs and Quarry bank, an industrial picturesque site with cave-like grottoes. In contrast over 60% of 19C grottos in the database remained unadorned. Some were rocky caves, such as Swinton in Yorkshire or Pencarrow in Cornwall, others were used for keeping goats as at Waddesdon and finally some were decorated by planting, especially ferns, such as Dewstowe in South Wales.[144]

Specific techniques

Once sourced and transported to the site, individual rocks needed to be moved and lifted into place. Smaller pieces could be dragged or rolled by hand using a lever and rollers on the ground plus some chains or, as at Lamport Hall in the 1840s, no lifting devices were required as the stones used were small enough for one man to lift.[145]

Edward Cooke's diaries reveal some strategies used at Biddulph Grange and later at his own house at Glen Andred. He writes of a 14cwt stump being 'hoisted over the wall', 'men getting up the big

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[142] Mowl, *Historic Gardens of Worcestershire*, p. 54; Michael Cousins, 'Hagley Park, Worcestershire', *Garden History*, Supplement (2007), p. 97.
[143] International Grotto Directory, 'Ascot Place Grottos'. <http://www.thespasdirectory.com/profilego.asp?ref=293E34> [accessed 14/09/2018].
[144] Historic England, 'Sir Walter Scott's grotto in bank of river Greta SW of Mortham Tower', listing 1310358, 1967; Symes, *The Picturesque*, p. 119; Hitching, *Rock landscapes*, p. 114.
[145] H.I., 'The rockery at Lamport Hall', *The Garden*, Vol 20 (1881), p. 217.

stones by Punnett's three horses' and having just 'heaved over a huge rock of 10 tons'. Many entries refer to 'work at fixing stones'.[146] Later, at Cragside, rocks were manoeuvred into position by men using only levers and a block and tackle, a curiously 'low tech' method on an estate where a plethora of new technologies existed. The rationale may lie in the site's topography where huge rocks were placed on steep slopes, a terrain where large machinery would not have been stable.

Machinery designed specifically for rock moving and lifting was claimed to be used at both Chatsworth and York, the site of Backhouse's rock garden. Paxton is said to have 'invented steam-powered machinery' by which the vast stones were 'moved and winched into place' while at York, Humphreys describes overcoming difficulties by 'the invention of rough but effective machinery for lifting them (the stones) finally into their respective positions'. According to Humphreys the machine broke down just as one of the heaviest stones was 'nearly raised to the apex of one of the compartments and was suddenly hurled down'.[147] Details, however, of these devices are not to be found in records.

F. W. Meyer, landscape gardener for 30 years at Robert Veitch & Son, described appliances he used for moving and carrying stones in journal articles at the end of the C19[148]. For stones weighing several tons he advised using 'a small trolley running on portable rails' (i.e. a tramway with trolley pushed/pulled by man). The rails were moveable, they could be 'shifted in any direction within a few minutes and were supported by wooden planks' (Figure 68).[149]

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[146] RHS Lindley Library, *E. W. Cooke at Biddulph Grange*.

[147] Devonshire, Duchess of, *The garden at Chatsworth*, (London, 1999) p. 74; Barre, *Historic gardens of Derbyshire*, p. 166; Noel Humphreys, 'A beautiful rock-garden', *The Garden*, Vol 7 (1875), p. 478; Personal communication from Brent Elliott, 22/03/2017.

[148] Meyer, F. W., 'Rock-gardens, ponds and streamlets in our pleasure grounds', *Journal of the Royal Horticultural Society*, Vol 23 (1899-1900), pp. 78-95.

[149] Meyer, *Rock and Water Gardens*, p. 13.

Figure 68. Equipment used by Meyer on a site in Paignton.
Note the pegs for laying out (foreground), temporary rails and trolley, wheelbarrows.

For smaller scale work he described 'a most handy appliance', a 2-wheeled trolley with a long pole which could double up as a lever, but for stones up to 2 tons in weight he stated 'they can be easily shifted without any appliances other than planks, rollers and iron bars or wooden hand-spikes (like a crow bar) as levers'. For hoisting (lifting) heavy stones he promoted use of 'a large tripod and double blocks' i.e. a block and tackle. He advocated use of an iron winch for lowering rather than raising stones as it allowed gentle movement.[150] Many of these tools had been used since medieval times or before.

Where natural rock faces featured in rockwork designs, they were excavated and moulded by hand. There are many sites from both the 18C and 19C where chisel marks can be seen in the rock faces (Figure 69). The scale of such works varied enormously. At Lamport Hall Sir Charles Isham, a keen horticulturist, 'chiselled a small hole through the centre of the stone and put soil in it so that the roots of the plant could by that means reach the ground'.[151] About 100 years

[150] Ibid p. 14.
[151] Anon, 'Lamport', *The Gardeners' Chronicle*, Vol 22 (1897), p. 209

earlier steps were being cut into the solid faces of the rock at Hawkstone, while at Plumpton Rocks 'benches were hewn out of rock' and at Rokeby caves 2m deep were cut into the limestone cliffs.[152]

Figure 69. Chisel marks seen on rockwork at Hawkstone Park 2017.

Once placed into the required position rocks or stones or decorative crystals either had to be balanced in situ or fixed in some way. For decorative stonework on grotto walls and ceilings, together with outside rockwork added to a brick core, lime mortar was the fixative of choice. However, this would only work for relatively light materials, anything heavier required an additional solution such as iron cramps which worked like large staples (Figure 70). At Bushy Park rubble was deliberately mortared against the brick face for the grotto decoration.[153] Willson suggested that fixing the material securely at

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[152] Pavord, 'Gardening', p. 34; Robert Hunter, 'Plumpton Rocks', *Yorkshire Gardens Trust Newsletter*, Issue 34 (Winter 2014), p. 2; Historic England, 'Sir Walter Scott's grotto'.
[153] Currie, Christopher Keith, 'Archaeological excavations at Upper Lodge, Bushy Park, London Borough of Richmond, 1997-1999'. <https://www.academia.edu/1428550/Archaeological_excavations_at_Upper_Lodge_Bushy_Park_London_Borough_of_Richmond_1997-1999> [accessed 08/12/2017].

Popes Grotto in Twickenham ‘presented something of a challenge’. The combined weight of rock and mineral was estimated to be over 30 tons. Both lime mortar and iron cramps were employed, ‘working from the floor upwards’. To fix materials hanging down from the ceiling, such as ‘icicles’ and stalactites ‘it may have been necessary to drill through the structure from above to insert supports for heavy materials’.[154] Other sites where cramps were used include Halswell Park and Oatlands. Cramps were regularly used in constructing buildings throughout both centuries, so this is a classic case of a ‘borrowed’ technique.

Figure 70. A 19th century metal cramp and remains of ironwork holding rocks together at Chatsworth.

[154] Willson, *Alexander Pope’s Grotto*, p. 21.

For outdoor rock creations individual rocks would be balanced on top of each other wherever possible as they required no fixing. Examples include use of lintel stones to complete archways, such as seen at Swinton Park and Aysgarth, and cantilevered rocks where the line through the centre of gravity was supported, as at Chatsworth. Where rocks nearly balanced, wedges (smaller stones of a suitable shape) could be used to stop tilting or toppling (Figure 71).[155]

Figure 71. Wedges in use and cantilevered rocks at Chatsworth.

Most spectacular of all large rocks placed without any fixings were 'balancing stones', for which one needed a good knowledge of physics and geology to create successfully. There are extant examples at Hewell Grange, Chatsworth and Friar Park. Mowl described the rock at Hewell Grange as a 'swinging monolith gate', while at Chatsworth the 'miniature Matterhorn' rock turned at the touch of a finger (it was mounted on an invisible swivel) and its neighbour is so balanced that it rocks up and down with little

155 W.I., 'Renovation of rock gardens', *The Gardener's Magazine* (1912), p. 278.

pressure. The example at Friar Park is made from Pulhamite so has no great weight to aid its balance.[156]

Stalactites were a favourite decorative feature for grotto ceilings, as they reinforced the idea of being inside a cave. A variety of construction techniques and materials were used. At the Gnoll in South Wales, a fusion of industrial and ornamental landscapes, two strategies were employed. Firstly, the sandstone ceiling to the grotto was lined with limestone to encourage natural stalactites to form. Secondly, man-made stalagmites were formed on the floor from carved limestone.[157] In the same vein the ceiling of the central hall at Thomas Goldney's grotto in Bristol was covered with closely fitted blocks of Bathstone (a type of oolitic limestone) from which pseudo-stalactites were carved in situ.[158]

In the mid-19C Winter Garden at Oakworth House stalactites were carved from natural stone and around the same period James Pulham was creating artificial stalactites out of Pulhamite such as the ones in Swiss Garden grotto/fernery (Figure 72).[159] In the 1880s Meyer was also making artificial stalactites using concrete on a flexible wire mesh base held in position by wire rods and nails. The stalactites were thought to be formed around thin wooden rods, held together with wire and possibly surrounding cones of paper or card – not too dissimilar to Pulham's method.[160]

A totally different approach had been taken in the mid-18C grottos of Surrey. Faux stalactites at Painshill and Oatlands were built using a

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[156] Mowl, *Historic Gardens of Worcestershire*, p. 87; Devonshire, *The Garden at Chatsworth*, p. 74; Crisp, *Friar Park,* p. 29.

[157] CADW Parks & Gardens Register, 'The Gnoll', NPRN 265660. <https://www.coflein.gov.uk/en/site/265660/details/gnoll-thegnoll-house-garden-neath > [accessed 12/12/17]; International Grotto Directory, *Gnoll Grotto*, <http://osborne.house.profilego.asp?ref=293F35> [accessed 12/12/18].

[158] Robert J. G. Savage, 'Natural history of the Goldney Garden Grotto, Clifton Bristol', *Garden History*, 17.1 (1989), p. 10.

[159] Jackson, *Shell Houses and Grottoes*, p. 25; Hitching, *Rock Landscapes*, p. 100.

[160] Carolyn Keep, *F. W.* Meyer *(1852-1906): A landscape gardener in Devon* (Exeter, 2015), p. 55.

former of wooden laths nailed to the ceiling onto which flakes of quartz and various spars were held in place by plaster (Figures 73, 74).[161]

Figure 72. Grotto at Swiss Garden showing faux-stalactites.

Figure 73. Wooden formers used in the reconstruction of stalactites at Painshill.

[161] Symes, *Mr Hamilton's Elysium*, p. 99; Symes, *Fairest Scenes*, p. 31.

Figure 74. Stalactites complete with decoration at Painshill grotto.

There were times when a rock was too big to handle and needed reducing in size. An unusual example of this occurred at Virginia Water in the 1750s. Thomas Sandby was looking for an enormous rock to give him a 'massive breadth in his composition'. He found one, but it was so large that 'he was under the necessity of breaking it with gunpowder'. He was extremely lucky that it broke into two nearly equal parts so that he was able to joint them together 'in their designed place to great effect'.[162] Here is an example where the traditional method of using wedges and levers was not used.

More often the challenge was to make a large rock from many smaller pieces. William Barron provided a description of his rockwork at Elvaston Castle in which he gives a 'recipe' using tufa with Roman cement mixed with sand and then coloured to 'become in effect a sold mass of rock'. At Chatsworth, Paxton created the three named rocks (Victoria, Albert and Wellington) from many rocks 'cemented together'.[163] The joins are visible today (Figure 75).

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[162] Anon, 'Virginia Water 1st January 1788'. <https://www.virginiawater.org.uk/scr/histlist.php?locit=&bid=11> [accessed 9/11/18].

[163] Barron, *The British Winter Garden*, p. 76; Devonshire, *The Garden at Chatsworth*, p. 75.

Figure 75. Victoria rock at Chatsworth, made up of lots of smaller rocks.

Rather than fixing rocks together with mortar or balancing them on top of each other to reach great heights, a retaining wall or a steep bank of earth could be used to support the rockwork. Lady Broughton's rockwork at Hoole House (1826), which reached over 30-feet high, was supported by a sandstone retaining wall. A huge Pulham outcrop at Highnam Court (1847) had a brick supporting wall holding it up, the remains of which can be seen today (Figure 76).[164]

[164] Hitching, *Rock landscapes*, p. 64.

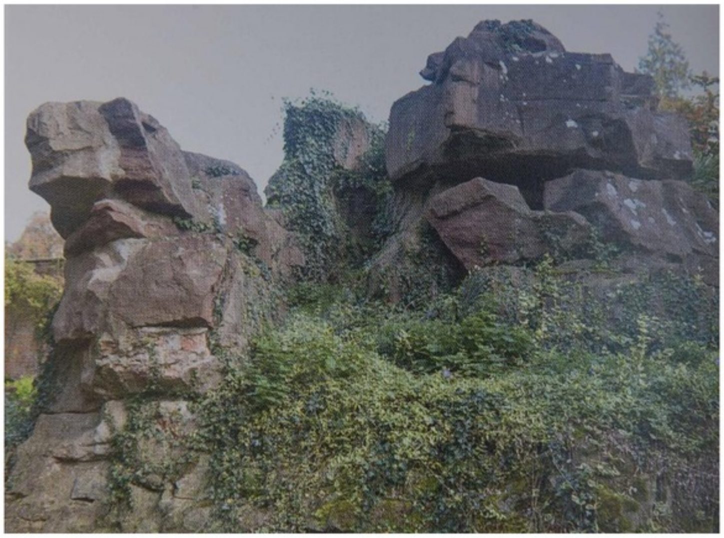

Figure 76. Highnam Court outcrop in pulhamite (above) and the retaining wall supporting it (below).

Joseph Paxton suggested that 'fragments of rock may be piled up to considerable height against steep banks'.[165] He appeared to have taken his own advice while constructing the Wellington rock at Chatsworth which was built into the steep slope of the hill rising above the house. At nearly 46-feet high (14m), it was constructed by cementing together many big pieces of rock. Today one can walk up the steps around it to a viewing platform and then you can see the

[165] Joseph Paxton, 'Rocks and rock-plants', *Paxton's Magazine of Botany*, Vol 12 (1846), p. 88.

estate road just above (Figure 77). Bringing materials via this road would have enabled individual rocks to be lowered onto the structure as it was being built rather than being lifted, and the embankment would support the rockwork as it grew in height.

Figure 77. Chatsworth: Wellington rock from the front (above) and from the back (below).

Use of embankments to support rocks was not new – it can be traced back to the time when Stonehenge was built. Consider how the ‘impost’ stones were positioned on top of the uprights without the aid of cranes. One theory proposed is that an artificial mound of earth was deposited on the site. Holes for the uprights were then dug through into subsoil, they were then dragged and upended into the holes so the tops were at ground level. The impost stones could then be levered into position and the artificial mound dismantled.[166]

Rockwork features in or near water required some means of keeping them watertight otherwise they would be dislodged by the action of the flowing water. The same was true of lakes. If they were constructed over existing subsoil then the water might drain away if that subsoil was porous. One answer to this was the process of ‘puddling’ which basically consisted of lining the feature with worked clay. At the beginning of the 18C Switzer’s advice was that ‘a pond must be 8 inches thick clayed’.[167]

The development of Portland cement in the 1820s, and the subsequent use of artificial stone such as Pulhamite, meant that puddling was no longer required to line pools and watercourses. Meyer, writing in the late 19C, showed how to line pools, streams and cascades with concrete which was subsequently masked with rocks and turf.[168] At Dewstowe (1895) pools were lined with Pulhamite cement and then edged with rockwork.[169] Concrete and artificial stone had replaced the need for puddling, however see Figure 78 below.

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[166] R. A. Stevens, *Building in History* (London, 1965), p. 6.
[167] Stephen Switzer, *Ichnographia Rustica: or the Nobleman, Gentlemen and the Gardener’s Recreatio* (London, 1718), p. 303.
[168] Keep, *F. W. Meyer*, p. 109.
[169] CADW Parks and Gardens Register, ‘Dewstow House & Garden, Caldicot’, NPRN 266053, p. 67.

Figure 78. Work on a section of Thames & Severn Canal c1904.
Labourers using puddled clay for canal lining.

A detailed account of constructing a cascade associated with a dam was given by John Grundy, a contemporary of Brown, working at Grimsthorpe.[170] Grundy was responsible for repairs to the stepped cascades in 1774 following partial collapse of the sluice head. Basically, he dismantled the cascade and re-built it. He laid a 3ft thick layer of clay across the whole width, covered with stones set on edge and pointed with lime grout, together with two further stone layers creating a stone 'skin' about 2ft thick over the clay. On this was laid the dressed stone for the cascade 'steps', each one not to exceed 1 foot in depth. He also added stone side walls covered with turf.[171]

The construction of rockwork features using artificial stone, such as Pulhamite was completely different. An initial framework would be built from clinker, waste stone, slag and sometimes wire frames and then the rockwork builders would coat the surface with layers of

[170] Roberts, 'Well-tempered clay, p. 15.
[171] Ibid p. 25.

Pulhamite mortar and work it to create the finish (basically a plastering job). They used various additives such as ochre, iron oxide, crushed charcoal, lime and chalk to colour the render and while the surface was still wet, they worked it with brushes, combs or even damp sacking to create the 'natural' looking finish (Figure 79).[172]

At Madeira Walk in Ramsgate, a Pulham site which was surveyed prior to restoration, it was suggested the overhanging rocks were originally made off-site then used for specific sections and covered with a base coat of Roman cement and a final coat of Pulhamite (Figures 80, 81).[173] At Dewstow an island was constructed by filling hessian sacks with cement, leaving them to set and then adding a layer of Pulhamite on top as this would be the only part to be seen once the pond was full of water.[174] Where Pulham used natural stone, as at Waddesdon and Sheffield Park, both built in the 1880s, he used conventional techniques described earlier.

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[172] Pavord, 'Elaborate 19th century grotto', p. 25; Beresford and Mason, *Durability Guaranteed*, p. 8.
[173] Ibid, p. 17.
[174] Photo displays in the Tropical House showing the empty Duck Pond during restoration. Site visit 2017.

Figure 79. Artist's image of Pulham's men constructing the Zig-zag path at Folkstone.
Note the wheelbarrow, bucket, hawk and finishing trowel.

Figure 80. Pulham artificial rockwork at Ramsgate c1900.

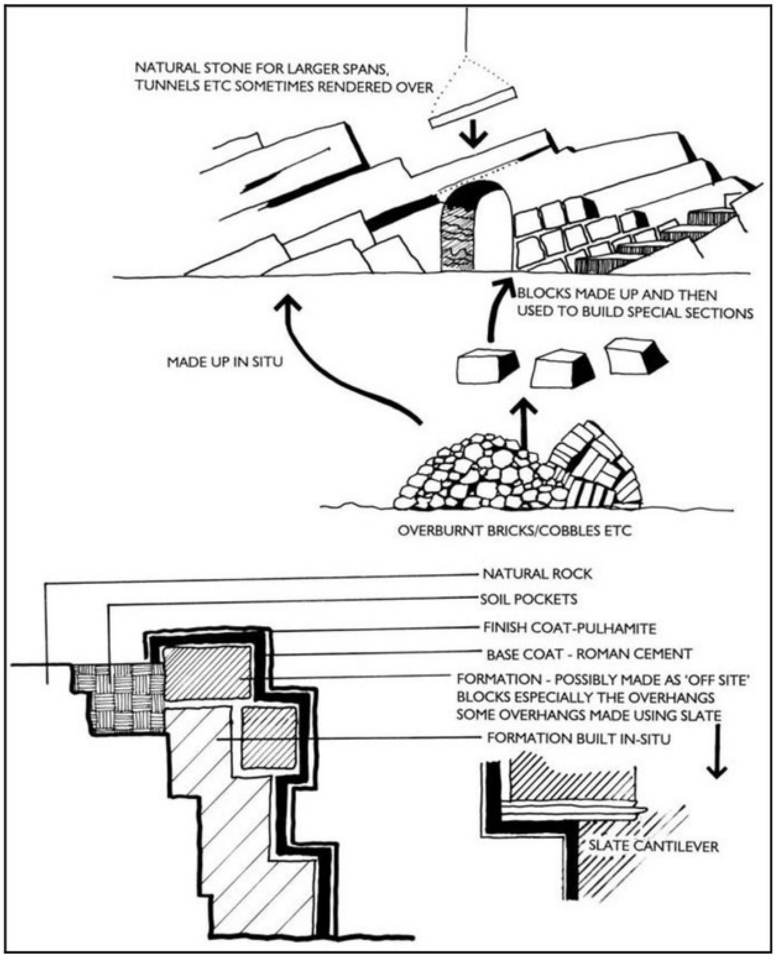

Figure 81. Details of construction at Ramsgate showing rockwork built in-situ and off-site.

Tools and machinery

In the early 18C gardeners' tools were mostly agricultural implements (Figure 82). These were used for many rockwork features and excavations for lakes such as those created by Brown.[175] Outside contractors often brought tools and equipment to site with them or relied on the estate providing them where local labour was involved. James Pulham & Son 'sends tackle for use, on hire, when there is

[175] Clarke et al., 'Engineering the landscape', p. 29.

none on the estate'. This is probably referring to lifting devices such as a movable block and tackle and ropes, chains and levers.[176]

Figure 82. Early 18C gardeners' tools. Engraving by Liger, 1723.

Written records from individual estates make very few references to tools used. A few snippets can be found, such as John Scott (poet), who told his biographer, that 'in making the excavation under the hill for the subterranean passage, he marched first, like a pioneer, with his pickaxe in his hand, to encourage his rustic assistants'.[177] The excavation mentioned was into a hill of solid chalk so a pickaxe,

[176] Pulham, *Picturesque Ferneries*, p. 32.
[177] Perman, *Scott's Grotto*, p. 4.

shovel and wheelbarrow would suffice. The solid chalk would have been self-supporting.

The estate accounts for Oatlands lists scaffolding, laths, nails, sledge-hammer, axes, cramps, spikes and chains and include payments for 'mending and setting tools'.[178] Almost a century later, Edward Cooke used a long wire to probe the soil around and between the buried rocks at Glen Andred and then scooped away the sand.[179] A comparison can be made with the 2013 restoration at Swiss Garden, carried out by Alan Bishop & Associates (specialists in Pulhamite rockwork renovation) where tools and materials used included a metal probe, a grout gun, stainless steel dowels, wire brushes, epoxy resin, masonry paint, piping bags and a coconut brush (Figure 83).[180] How many of these would the Duke of Newcastle, John Scott or Edward Cooke have recognised?

Figure 83. Grout gun in use during restoration at Swiss Garden fernery/grotto.

Early photographic evidence from the 1850s onward provides further details of tools and equipment used at various stages of the build process (Figures 84, 85).

[178] Symes, 'New light on Oatlands Park', p. 146.
[179] Anon, 'Edward W. Cooke, R.A. Obituary', p. 41.
[180] Alan Bishop & Associates, 'Swiss Garden restoration'.

Figure 84. Lake excavation at Burnby Hall gardens 1904.
Still using wheelbarrows and planks and basic tools.

Figure 85. Constructing the ravine at Lilford Hall, Northamptonshire.
Note use of shovels, pickaxes and levers.

They also support the assertion that rock building techniques were borrowed from other industries. They confirm that mixed technologies, both old and new, were utilised where necessary as the images below show (Figures 86-92).

Figure 86. Widening the tunnel at Edge Hill, Liverpool c1872. Note use of hand-cranked derrick cranes, wooden scaffolding and a steam train in bottom left had corner.

Figure 87. Steam excavator used during Katrine aqueduct construction, 1880s.
Note the use of horses and temporary track and steam engine.

Figure 88. Stonehenge – 10-ton lintel being lifted by hand crane in 1920.

Figure 89. Mechanised farming 1907 – use of horse-driven gin/motor to drive a conveyor belt to build haystacks.

Figure 90. Labourers making puddling clay to provide a watertight lining for Thames and Severn Canal c1904. Note use of temporary railway/tramway, tipping wagons and steam engine.

Figure 91. Cherwell New Cut being hand-excavated in 1884. Note extensive use of spades, wheelbarrows and wooden planking. Compare with Figure 84.

Figure 92. Hand excavation of Manchester ship canal c1889.
Note use of temporary railway for removing spoil.

Each of the 81 sites in the database have contributed something to the overall picture of how rockwork features were built. For further examples illustrating the key stages in the build process see Appendix 1. In contrast to the varying amounts of information found from individual sites discussed so far, Wisley rock garden, built in 1911, had enough evidence to provide a comparative case study. James Pulham gave a paper to the RHS members on 13th August 1912 describing many areas of its construction. Table 3 summarises the elements of the build process and figures 93-95 show the results.[181]

[181] Pulham, 'The Wisley rock and water garden', pp. 225-233.

Table 3: Wisley Rock Garden 1911. Construction detail provided by James Pulham

Stage in the construction process	Evidence
Contract details	-job originally given to F W Meyer but he died suddenly in 1906 leading to a hiatus. -five firms, including Backhouse, tendered for the fixed price job and Pulham won. Competitors had to submit samples of stone they proposed to use. -contractor had to work to a fixed sum. -managed by RHS Committee.
Choosing the site	-site ~1.5 acres covered at the top with rough turf. -NW facing slope with 65ft steep descent with series of ponds at the bottom. - no natural water supply on site, except lily ponds at bottom of slope. -bedrock is Bagshot Formation (sand) meaning rock needed to be imported.
Procurement of materials	-rock brought in from quarries near Godalming c14 miles away. Transported by road. -fixings and pulhamite mortar provided by contractor.
Surveying and setting out	-trial holes made to identify soil properties. -site was staked out with pegs identifying position of stream, paths and tracks.
Design/plans	-designed by Edward White landscape-gardener. -no formal plans presented by Pulham. -style is a terraced alpine garden. -changes made during the construction phase, discussed at RHS sub-committee.
Excavation	-excavation carried out by hand. -tramway used for moving spoil. -old land drains found and conducted into the stream at nearest point. -areas identified that were constantly damp – used for specific plants. -care was taken to obtain as many south-facing aspects as possible to accommodate variety of planting.
Foundations	-no details provided but would have had to form a base of stone to avoid final rockwork slipping.
Water management	-old well re-used as main water supply.

Water management (ctd.)	-petrol engine attached to centrifugal pump moved water to the underground reservoir at the top of the site. -water flows down the stream and waterfalls by gravity. -junctions in supply pipe connected to stand pipes – used for watering the plants. -use of perforated lead pipes for underground watering in the moraine area. -paths taken out to depth of 6" with trench 6" deeper along middle to accommodate land drains which discharge into the cave, bog-garden or ponds. -each section of stream between waterfalls has a stop valve to allow it to be separately drained and cleaned. -cavern for filmy ferns created re-using land drains to bring water to top of cave to drip. -bog-garden created on three levels below the cavern. Ground here puddled and stepping stones placed to allow close access to plants.
Final fix	-planting took place from March 1911 to January 1913 using dwarf conifers, alpines and bulbs. -donations came from individuals and nurseries including Veitch (rhododendrons & bamboos), Pulham (dianthus), Farrer's Craven Nursery (primulas and saxifrages), Ellen Willmott, Lady Du Cane and E.A. Bowles (2 collections).
Tools & techniques	-traditional tools in use – wheelbarrows, spades, simple levers. -each individual stone bedded in soil at varying depths to suit the planting and laid on its proper bed ie as quarried. -interstices left between each stone for subsequent planting. -land drains fitted in the principal paths, discharging to cave or bog garden. -steps added for visitors with open joints to accommodate planting.
Materials used	-Sussex sandstone. -stream bed concreted rather than puddled. Edges disguised. -12 waterfalls – 'special cement' (Pulhamite or similar) same colour as stone, used to fix stones to avoid leaks. -surface of paths paved with rough, irregular stone slabs.
Transport of materials on site	-two tramways used on site– one for moving spoil from groundworks, the second for transporting stone from road to the site (about 400 yards). -stone moved to various parts of garden by means of tramway 'and other suitable appliances' – eg portable crane.
Problems encountered	-instability of the soil caused the garden to be rebuilt on a number of occasions + maintenance issues including petrol pump breakdowns, winter damage to planting and shrubs growing too large

Figure 93. Wisley rock garden during construction. Note use of temporary tramway and low-level wagon to move rocks being guided by hand. Also use of planks for support.

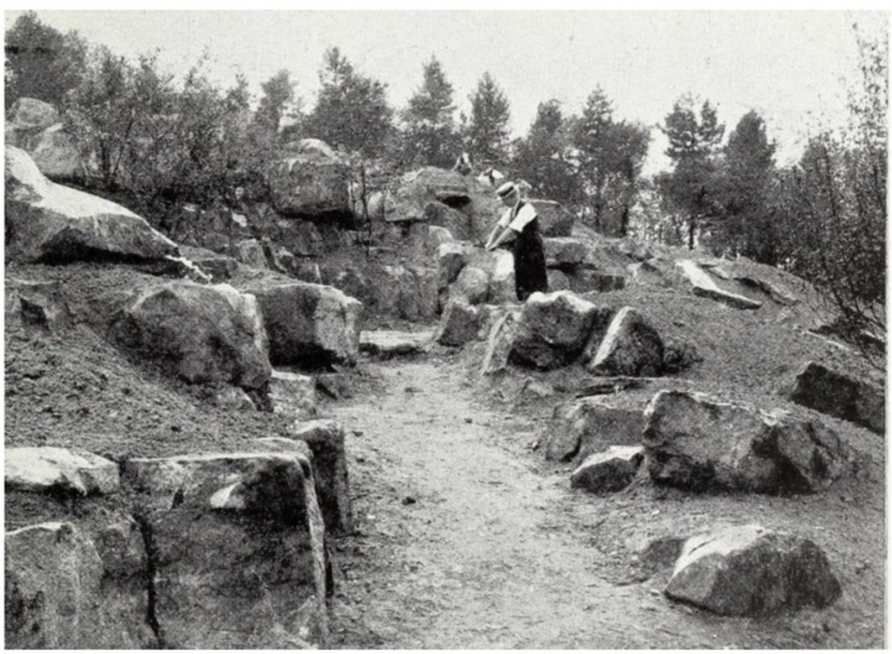

Figure 94. Wisley in the course of construction, 1911.

Figure 95. Wisley cave for filmy ferns, 1911.

This case study is a useful comparator as it clearly indicates where significant changes had or had not occurred since 1700. Unchanged over the 200-year period was hand excavation, use of traditional tools such as spades, crowbars and wheelbarrows, use of land drainage techniques and use of types of temporary railway to move stone around on site. The main areas of significant change were the power to run the pump and the use of new materials. In the early 1700s power for pumps came from wind, water or animal, while at Wisley a petrol engine was used, this was the beginning of the age of early automotive transport. Materials available at the beginning of the 20C included different types of concrete, artificial stone and steel whilst at the beginning of the 18C choices were more limited. Many aspects of the earlier exemplars are reflected in this case study and the photographic evidence matches that from infrastructure projects in associated industries.

This chapter has provided details of all the phases of construction, identifying what changed and what did not over the chosen time period. Conclusions are drawn in the following chapter, together with ideas for further research.

Chapter 5
Conclusions

This research presents the first full account of the stages in constructing rockwork features throughout the chosen timeframe, a picture built up from analysis of written accounts, together with contemporary images and verified by photographic evidence from 1850s onward. Whilst a complete account of the construction of rockwork features on any individual site remains elusive, evidence has been presented for all the identified stages in the build process, mirroring the stages in a traditional house build, which answers the first two key research questions.

Whilst all the identified stages were present, the design stage required different techniques such as dynamic 3-d modelling and trial and error rather than reliance on detailed architectural drawings. The design drawings found contained insufficient detail for a rockwork builder, although such drawings were made later by visitors. Suitable materials were obtained via a variety of routes including making the most of on-site materials, recycling industrial waste or old building materials and taking rock from nearby beauty spots. Owners had no qualms about environmental vandalism or using their extensive personal and family contacts to obtain materials for them, often accepted as gifts. Forms of transport changed over time in line with new innovations – sea and river journeys, toll-roads, canals and then steam trains, but one constant was the continued use of tramways throughout the 200-year period, especially for moving materials around the site.

Another constant throughout the chosen time period was the use of hand-excavation, even when mechanical excavators were available. The scale of excavations was often huge, requiring large amounts of labour and taking several years to complete. This pattern was replicated in many infrastructure projects such as building canals, railways and aqueducts.

The research findings confirm that rockwork builders extensively borrowed techniques from associated industries, answering the third key question. Evidence was found for use of cut and cover techniques in creating underground tunnels and grottos (from canals and railways), use of pillar and stall methodology for caverns hewn out of solid rock (from underground mines and quarries), use of vaulted ceilings (from cathedral building), use of early steam engines for pumping water (from coal mining), use of tramways for moving heavy loads (from quarrying), water management techniques (from farming) and types of walls, roofs and brickwork (from building).

Creators of rockwork features displayed ingenuity in building water management systems, overcoming problems such as no natural water supply, difficult local topography, flooding or silting up. Systems were often complex with many components and served several purposes. Visitors were catered for by clever use of turning individual water features on/off, creating spectacle and theatre.

There was little change in the hand tools and lifting equipment used throughout the time period. Levers, block and tackle, winches and hand-operated cranes were repeatedly used. In the context of building a rockwork feature on a restricted site this would be more efficient than mechanised cranes, a situation where technological innovation was not appropriate. There were changes in the power sources available for machines which followed developments in the industrial revolution but not necessarily at the same rate. At the beginning of the 18C wind, water and animal power were used to drive windmills, watermills and cranes or winches. By the end of the century steam-driven engines were widely used, then came hydraulic pumps and cranes and finally petrol driven combustion engines by the beginning of the 20C. Many of these machines were used in constructing rockwork.

From a modern perspective, environmental approaches were mixed. On the one hand there was extensive use of recycled materials, available because of the rise in industrial activity. In contrast, owners and contractors thought nothing of taking suitable rocks from local beauty spots, as happened in a similar fashion with the Victorian fern craze.

Another change over the time period was the range of materials available and this generally followed technological innovations. Wooden pipes used at the beginning of the 18C were overtaken by rolled steel, naturally occurring rocks were used exclusively in the 18C, while artificial stone was widely used in the 19C and puddling with clay was largely overtaken by use of concrete.

Although this research has not focused specifically on the human element of the construction process, it is clear that owners, gardeners and contractors all showed flair, initiative and determination in their creations. Having unsuitable bedrock did not put off owners from building rockwork features, they were willing to pay for transporting materials from other parts of the country or even from abroad. Features were often designed and constructed to cater for visitors. From clever use of visual effects to create illusions, to choice of unusual materials, to engineering a new type of sluice to get an even more spectacular display from a cascade and possibly inventing a special steam powered machine for lifting rocks, these rockwork builders learnt as they went along and thought outside the box, creating lasting rockwork features which were often seen as wonders of their day (Figure 96).

THE WALK THROUGH THE WATER. (1. THE MYSTERY.)

THE WALK THROUGH THE WATER. (2. BEHIND THE SCENES.)

Figure 96. Rockwork creators showing a sense of fun. Walking on water illusion at Friar Park.

Further research

Recent restoration effort, including archaeological research, together with collections of early photographic images, have provided valuable evidence of how rockwork features were built for this project and further investigations in this area would be valuable as new finds are constantly being made.

The research has also identified further questions which, as yet, remain unanswered. For example, who did all the work (large workforces were often required using both specialists and unskilled labourers)? Was there a link between equipment used for handling rocks and that used for handling mature trees for transplanting (Paxton and Barron did both and lived less than 30 miles apart)? How much did a knowledge of geology play in the construction process (many rockwork builders were keen amateur geologists and new discoveries were being made throughout the 200-year period)? Were the industrialist/entrepreneur owners more likely to use new technologies than their counterparts who had inherited estates (research into technologies used in country houses suggests this might be the case in that context)? These areas could benefit from further research to add to the picture already created here.

Appendix 1
The database of sites

This appendix comprises five tables which highlight key information from the database. The 81 sites are spread across England, Wales and Scotland, in urban areas as well as countryside. Visits were made to 39 of the sites. Table 1 lists all the sites with their county, original owner at the time the rockwork was created, and current owner where applicable. Some of the sites have been lost or are in divided ownership. The dates give are as close as possible to when the rockwork feature(s) were started.

Table 2 identifies the key rockwork features considered, the designer and/or contractor where known and the style descriptors. The exemplars used in Chapter 2 are highlighted in yellow. The original topology and bedrock are listed in Table 3, together with an indicator of whether the local bedrock would have been suitable for use in creating rockwork features. The bedrock was identified using the site postcode with British Geological Survey maps. Finally, this table gives an indication of whether the rockwork features were underground, built up from ground level, excavated or built in an already excavated area such as a quarry. Table 4 identifies the chosen type(s) of rock used in the construction, together with an indication of the distance imported rocks were transported to get to the site. Table 5 gives an overview of the site-specific exemplars related to the stages of construction used in Chapter 4. Exemplars used in that chapter are highlighted in brown and other unused exemplars or ‘snippets’ are listed.

Table 1: Geographical spread and ownership of sites

No	Name	County	Original owner	Current owner	Dates
1	Bushy Park	London	Earl of Halifax	Royal Parks	1710
2	Popes grotto	Middx	Alexander Pope	School	1720
3	The Gnoll	Glamorgan	Sir Herbert Mackworth	Council	1730
4	Prior Park	Bath	Ralph Allen	NT	1734
5	Stowe	Buckinghamshire	Viscount Cobham	NT	1738
6	Goldney	Bristol	Thomas Goldney	Bristol Uni	1739
7	Belton	Lincs	Sir John Brownlow	NT	1740
8	Leasowes	W Midlands	William Shenstone	Council	1743
9	Warmley House	S Gloucester	William Champion	Museum/private	1746
10	Hagley	W Midlands	George Lyttelton	private	1747
11	Stourhead	Wiltshire	Henry Hoare	NT	1748
12	Hackfall	N Yorkshire	John Aislabie	Woodland Trust	1749
13	Hawstone	E Shropshire	Sir Rowland Hill	private	1750
14	Enville	W Midlands	Earl of Warrington	nothing left	1750
15	Claremont	Surrey	Duke of Newcastle	NT	1750
16	Virginia Water	Surrey	Duke of Cumberland	Crown	1753
17	Halswell Park	Somerset	Sir Charles Tynte	Private	1754
18	Plumpton Rocks	Yorkshire	Daniel Lascelles	Trust	1755
19	Painshill	Surrey	Charles Hamilton	Trust	1760
20	Croome Court	Worcestershire	Earl of Coventry	NT	1760
21	Oatlands	Surrey	Earl of Lincoln	nothing left	1762
22	Rokeby	Co Durham	J S Morritt	HHA	1769
23	Scotts grotto	Hertfordshire	John Scott poet	Ware Town Council	1770
24	Chelsea Physic Garden	Chelsea	Society of Apothecaries	CPG Company	1773
25	Badger Dingle	Shropshire	Isaac Hawkins Browne	Divided	1780
26	Haford	Ceredigion	Thomas Johnes	Trust	1780
27	Ascot Place	Berkshire	Daniel Agace	private	1780
28	Quarry Bank	Cheshire	Samuel Greg	NT	1784
29	Bowood	Wiltshire	Marquess of Lansdowne	hotel	1785
30	Thoresby	Notts	Viscount Newark	private	1791
31	Wardour Castle	Wiltshire	Baron Arundell	EH	1792
32	Fonthill	Wiltshire	William Beckford	private	1794
33	Swinton	N Yorks	William Danby	Hotel	1800
34	Sezincote	Gloucestershire	Sir Charles Cockerell	Private	1800
35	Coleorton Hall	Leicestershire	Sir George Beaumont	private	1802
36	Kidbrooke Park	Sussex	Charles Abbott	school	1803
37	Belsay Hall	Northumberland	Sir Charles Monck	EH	1806
38	Redleaf House	Kent	William Wells	divided	1807
39	Hewell Grange	Worcestershire	6th Earl of Plymouth	Prison	1812
40	Basingill	Cumbria	Isabella Wakefield	Env Agency	1821
41	Hoole House	Cheshire	Lady Broughton	housing	1826
42	Syon Park	Middx	Duke of Northumberland	Private	1830
43	Pencarrow	Cornwall	Sir William Molesworth	private	1831
44	Elvaston Castle	Derbyshire	Earl of Harrington	Council/NT	1838
45	Woodlands	Hertfordshire	John Warner	Lost	1838
46	Chatsworth	Derbyshire	Duke of Devonshire	NT	1842
47	Biddulph Grange	Staffordsdhire	James Bateman	NT	1842
48	Highnam Court	Gloucestershire	Thomas Gambier Parry	Private	1847
49	Lamport Hall	Northamptonshire	Sir Charles Isham	Private	1848
50	Osmaston Manor	Derbyshire	Francis Wright	Private/lost	1849
51	Welbeck Abbey	Nottinghamshire	Duke of Portland	Private	1854
52	Sydnope Hall	Derbyshire	R. B. Barrows	Lost	1858
53	Oakworth House	W Yorkshire	Sir Isaac Holden	Council	1864
54	Glen Andred	Sussex	Edward Cooke	Private	1865
55	Battersea Park	London	Commission	Council	1865

Table 1 continued

No	Name	County	Original owner	Current owner	Dates
56	Audley End	Essex	Lord Braybrooke	EH	1867
57	Stancliffe Hall	Derbyshire	Sir Joseph Whitworth	Private	1870
58	Ascog Hall	Isle of Bute	Alexander Bannatyne Stewa	Private	1870
59	Cragside	Northumberland	Lord William Armstrong	NT	1870
60	Brodsworth Hall	Yorkshire	Charles S. A. Thellusson	EH	1870
61	St Fagans Castle	Glamorgan	Lady Mary Windor-Clive	Museum	1872
62	Swiss Garden	Bedfordshire	Jospeh Shuttleworth	Trust	1876
63	St Albans Court	Kent	William Oxenden Hammon	Private	1877
64	Highbury Park	Birmingham	Joseph Chamberlain	Council park	1878
65	Waddesdon Manor	Buckinghamshire	Baron Ferdinand de Rothsc	NT	1881
66	Kew Gardens	Surrey	Sir Joseph Hooker (Director	Kew	1882
67	Warley Place	Essex	Ellen Willmott	Wildlilfe Trust	1882
68	Sheffield Park	E Sussex	Earl of Sheffield	NT	1882
69	Munstead Wood	Surrey	Gertrude Jekyll	private	1883
70	East Park	Yorkshire	Hull City Council	Council	1887
71	The Dell	Surrey	Baron Schroder	housing	1888
72	Ewell Court House	Surrey	John Bridges	trust	1892
73	Madiera Walk	Kent	Ramsgate council	Council	1894
74	Dewstow	Monmouthshire	Henry Oakley	private	1895
75	Wotton House	Surrey	William John Evelyn	private	1896
76	Grove House	London	Raoul Bedingfield	University	1897
77	Friar Park	Oxfordshire	Sir Frank Crisp	private	1898
78	Aysgarth rock garden	N Yorkshire	Frank Sayer Graham	private	1906
79	Merrow Grange	Surrey	Francis Baring Gould	divided	1907
80	Gatton Park	Surrey	Jeremiah Coleman	Trust/NT	1910
81	RHS Wisley	Surrey	Royal Horticultural Society	RHS	1911

Table 2: Key rockwork features and style descriptors

No	Name	Dates	Key Features	Contractor/ designer	Style descriptors
1	Bushy Park	1710	stepped cascade, faux grottos	unknown	Formal Baroque water garden
2	Popes grotto	1720	grotto	Pope	underground grotto, geological collection
3	The Gnoll	1730	cascades, grotto	Switzer style	early industrial/decorative combined (iron and brass works)
4	Prior Park	1734	cascade, grotto	advice from Pope & Brown	early landscape garden, Palladian Bridge
5	Stowe	1738	cascade, grotto	Kent	pre-pictureque cascade + ruin, architectural grotto
6	Goldney	1739	grotto	Goldney	underground grotto,shell + geological collection
7	Belton	1740	cascade	Brownlow	early picturesque with ruin
8	Leasowes	1743	cascades	Shenstone	naturalistic cascades, circuit garden
9	Warmley House	1746	grotto	Champion	early industrial picturesque (brassworks)
10	Hagley	1747	cascades	Lyttelton	embellished natural cascades, Palladian bridge, circuit garden
11	Stourhead	1748	cascade, grotto	Kent, Flitcroft, Lanes	formal architectural
12	Hackfall	1749	rock & water	Aislabie	sublime/picturesque; woods, rock , water, sound
13	Hawstone	1750	grotto, narrow paths, precipices	Hill, Emes (lake)	embellished cliff in flat landscape, picturesque/sublime
14	Enville	1750	cascades	Shenstone	naturalistic cascades, circuit garden
15	Claremont	1750	grotto, cascade	Kent, Wright, Pickford, Lanes	first naturalistic (but artificial) cave-grotto
16	Virginia Water	1753	cascade, grotto, lake	Sandby	naturalistic
17	Halswell Park	1754	cascades, grotto	Wright	grotto screen covering dam; bridges over dams leading to cascades
18	Plumpton Rocks	1755	rock & water	Carr (lake dam)	natural rocky outcrop with picturesque dressing
19	Painshill	1760	cascade, grotto, free standing rock	Lanes, Pickford	rusticated grotto, internal decoration, scattered rockwork; circuit garden
20	Croome Court	1760	grotto	Brown	rusticated grotto
21	Oatlands	1762	grotto	Wright, Lanes	two-storey structure built against a bank, highly decorated
22	Rokeby	1769	cave grotto	unknown	primitive, cave-like grotto, undecorated at confluence of 2 rivers
23	Scotts grotto	1770	grotto	Scott	underground grotto with connecting tunnels
24	Chelsea Physic Garden	1773	free standing rock	Curtis & Bristow	collection of different rocks
25	Badger Dingle	1780	caves	Emes	picturesque wilderness, ravine with stream, pools
26	Haford	1780	cascades, tunnels	Johnes	sublime, circuit walks, embellished rockwork
27	Ascot Place	1780	cascade, grotto	Lanes	rusticated lakeside grotto, lavish decoration, picturesque
28	Quarry Bank	1784	caves	Greg	cave-like grotto, undecorated; industrial picturesque (cotton mill)
29	Bowood	1785	grotto, cascades, free standing rock	Hamilton, Lanes	scattered rockwork, wild, primitive, picturesque
30	Thoresby	1791	cascade	Repton	earlier rustic cascade altered by Repton
31	Wardour Castle	1792	grotto	Brown, Lanes	primitive style grotto + rockwork
32	Fonthill	1794	grottos	Lanes	subterranean and above ground grottos, primitive & architectural
33	Swinton	1800	grotto, scattered rockwork	Mickle	scattered rockwork around lakes, set piece grotto, henge
34	Sezincote	1800	rock formations, grotto	Daniell	Indian style garden, 3 grottos within bank
35	Coleorton Hall	1802	grotto	Wordsworth	quarry; winter garden with grotto
36	Kidbrooke Park	1803	cascade, pools	Repton	adaptation of 18C park; water management
37	Belsay Hall	1806	quarry	Middleton	garden within a quarry; picturesque
38	Redleaf House	1807	rocky outcrops	Wells	excavated garden, natural rocky outcrops
39	Hewell Grange	1812	quarry	Shenstone, Brown, Repton	quarry garden; megaliths
40	Basingill	1821	quarry	Wakefield	industrial picturesque/sublime (gunpowder mills)
41	Hoole House	1826	free standing rockwork	Lady Broughton	imitation of nature, scale model of Savoy Alps

Table 2 continued

No	Name	Dates	Key Features	Contractor/ designer	Style descriptors
42	Syon Park	1830	free standing rockwork	Forrest	contrast - irregularity of rocks & smoothness of beds or lawn
43	Pencarrow	1831	rocky outcrops	Corbett	imitation of nature; 'Dartmoor' effect
44	Elvaston Castle	1838	free standing rockwork	Barron	imitation of nature; rockwork round lake
45	Woodlands	1838	cliffs and caves	Pulham	1st garden using pulhamite, cliffs & caves hiding a view
46	Chatsworth	1842	free standing rockwork	Paxton	imitation of nature
47	Biddulph Grange	1842	rockwork to create compartments	Bateman/Cooke	rockwork as structural framework for garden rooms
48	Highnam Court	1847	cascades, grottoes, fernery	Pulham	unadorned grotto, use of pulhamite and yorkstone
49	Lamport Hall	1848	rockwork in front of house	Isham	exception of rule of congruity; planting scaled to size of rocks
50	Osmaston Manor	1849	cascades, fernery	Paxton?, Pulham, Milner	natural rock garden style, Pulham fernery
51	Welbeck Abbey	1854	tunnels	Duke of Portland, Pulham	network of underground corridors & rooms, pulhamite-lined tunnel
52	Sydnope Hall	1858	cascades	Young	natural style; waterfall
53	Oakworth House	1864	cascades, grotto	Aucaunte	rockwork within winter garden, concrete rustic work
54	Glen Andred	1865	rocky outcrops	Cooke	rockwork as structural framework; excavation of rocky outcrops
55	Battersea Park	1865	cascade, free standing rockwork	Cubitt, Pulham	artifical rockwork to screen view; geological accuracy
56	Audley End	1867	cascade	Brown (18C), Puham	Alpine theme, raging torrents of water (artifical channel)
57	Stancliffe Hall	1870	quarry	Milner	quarry garden; excavations
58	Ascog Hall	1870	fernery	E. Bateman	conservatory landscape, rockwork within a sunken fernery
59	Cragside	1870	cascades, scattered rockwork	Armstrong, Hudson	scattered rockwork on v steep site; natural style
60	Brodsworth Hall	1870	quarry garden, rockery, grotto	J. Barron	quarry garden within Italianate pleasure grounds
61	St Fagans Castle	1872	cascades, ponds	Pulham	waterfalls, ponds, bridge; natural style
62	Swiss Garden	1876	grotto, fernery	Pulham	rockwork within a fenery, Swiss picturesque
63	St Albans Court	1877	sunken garden	Pulham	sunken rock garden, recently re-discovered
64	Highbury Park	1878	cascade, free standing rockwork	Milner, Pulham	series of gardens, alpine rock garden, fernery
65	Waddesdon Manor	1881	grottoes, cascades	Pulham, Harpham	large rock and water gardens with aviary
66	Kew Gardens	1882	alpine rock garden	Hooker (Director)	excavated; imitation of nature; Pyrenean stream-bed
67	Warley Place	1882	ravine with stream and cave	Backhouse, Willmott	excavated alpine rock garden
68	Sheffield Park	1882	cascades, lakes	Brown (18C), Pulham	landscape park with water and woodland; cricket ground
69	Munstead Wood	1883	sunken rockwork	Jekyll	small rockwork on edge of woodland
70	East Park	1887	Khyber pass	Peak	imitation of nature, scale model, exotic scenery in public park
71	The Dell	1888	rocky outcrop, pools, water tower	Pulham	Extensive rock garden with pools on a hill
72	Ewell Court House	1892	cascades, fern grotto	Pulham	domed grotto fernery adjacent to glasshouse plus rocky stream
73	Madiera Walk	1894	cascade, caves, coloured rocks	Pulham	picturesque, natural construction creating artifical gorge alongside road
74	Dewstow	1895	grottoes, fernery, ponds	Pulham	underground grottos and tunnels, ponds, geological accuracy
75	Wotton House	1896	grotto, fernery, cascade	Pulham	unadorned grotto, scattered rockwork along stream, fernery grotto
76	Grove House	1897	grotto	Harpham	grotto within formal gardens with lake and sham bridge
77	Friar Park	1898	alpine rock garden, Matterhorn	Backhouse, Pulham, Harpham	imitation of nature, exotic scenery
78	Aysgarth rock garden	1906	cascade, walk-through grotto	Backhouse	alpine rock garden with mountain stream and cascade
79	Merrow Grange	1907	grotto, fernery, caves	Pulham	linking conservatory landscape with outside rockeries
80	Gatton Park	1910	pool, cascade	Brown (18C), Pulham	rock escarpment with naturalistic pools
81	RHS Wisley	1911	cascade, pools, terraces	Pulham, White	terraced alpine garden

Table 3: Site topology and bedrock

No	Name	Dates	Postcode	Original topology	BGS bedrock	Suitable?	Type of rockwork features
1	Bushy Park	1710	TW12 2EJ	flat/in flood-plain	clay	X	built up
2	Popes grotto	1720	TW1 4QQ	sloping from river	clay	X	underground
3	The Gnoll	1730	SA11 3QJ	hillside	sandstone	√	built up
4	Prior Park	1734	BA2 5AH	hillside	oolitic limestone	√	built up
5	Stowe	1738	MK18 5EQ	undulating	limestone	√	built up
6	Goldney grotto	1739	BS8 1BH	flat/underground	Millstone grit	√	underground
7	Belton	1740	NG32 2LS	flat	Mudstone w limestone nodules	X	built up
8	Leasowes	1743	B62 8DH	ridge beteeen 2 valleys	Halesowen sandstone	√	built up
9	Warmley House	1746	BS30 8XT	rising ground	sandstone	√	underground
10	Hagley	1747	DY9 9LG	steep sloping	sandstone	√	built up
11	Stourhead	1748	BA12 6QF	sloping	sandstone	√	built up
12	Hackfall	1749	HG4 4DY	steep sloping	mudstone/silstone/sandstone	√	built up
13	Hawstone	1750	SY4 5JY	flat with cliff	red sandstone	√	excavated
14	Enville	1750	DY7 5HA	steep sloping	sandstone	√	built up
15	Claremont	1750	KT10 9JG	undulating	Bagshot formation - sand	X	built up
16	Virginia Water	1753	GU25 4QF	flat	Bagshot formation - sand	X	built up
17	Halswell Park	1754	TA5 2DH	hillside	Slate (sandstone nearby)	√	built up
18	Plumpton Rocks	1755	HG5 8NA	rock outcrop	Millstone grit (sandstone)	√	excavated
19	Painshill	1760	KT11 1JE	undulating	Bagshot formation - sand	X	built up/excavated
20	Croome Court	1760	WR8 9DW	undulating	Mudstone	X	built up
21	Oatlands	1762	KT13 9HB	sloping	Bagshot formation - sand	X	built up
22	Rokeby	1769	DL12 9RZ	natural gorge	limestone	√	excavated
23	Scotts grotto	1770	SG12 9JG	hillside	chalk	√	underground
24	Chelsea Physic Garder	1773	SW3 4HS	flat	clay	X	built up
25	Badger Dingle	1780	WV15 5SL	natural gorge	sandstone	√	excavated
26	Haford	1780	SY23 4AG	steep hill/valley	sandstone/mudstone	√	excavated
27	Ascot Place	1780	SL5 8QF	flat	sand/silt & clay	X	built up
28	Quarry Bank	1784	SK9 4LA	steep valley	sandstone	√	excavated
29	Bowood	1785	SN11 9PQ	undulating	sandstone	√	built up
30	Thoresby	1768	NG22 9EP	undulating	sandstone/pebbly	√	built up
31	Wardour Castle	1792	SP3 6RR	undulating	mudstone	X	built up
32	Fonthill	1794	SP3 5SH	undulating	chalk with limestone/sandstone nearby	√	built up/excavated
33	Swinton	1800	HG4 4JH	flat	oolitic limestone	√	built up
34	Sezincote	1800	GL56 9AW	sloping	sandstone	√	built up

Table 3 continued

No	Name	Dates	Postcode	Original topology	BGS bedrock	Suitable?	Type of rockwork features
35	Coleorton Hall	1802	LE67 8FZ	mostly flat	sandstone	√	in a quarry
36	Kidbrooke Park	1803	RH18 5JA	undulating	sandstone/siltstone interbedded	√	built up
37	Belsay Hall	1806	NE20 0DX	flat	mudstone/sandstone/limestone	√	in a quarry
38	Redleaf House	1807	TN11 8BW	sloping	sandstone nearby	√	excavated rocky outcrops
39	Hewell Grange	1812	B97 6QY	undulating	sandstone	√	in a quarry
40	Basingill	1821	LA8 0JX	steep hill	limestone	√	in quarry
41	Hoole House & garder	1826	CH2 3BF	flat	sandstone, pebbly	√	built up
42	Syon Park	1830	TW8 8JF	flat	clay	X	built up
43	Pencarrow	1831	PL30 3AG	undulating	slate & siltstone	√	built up
44	Elvaston Castle	1838	DE72 3EP	flat/swampy	mudstone	X	built up
45	Woodlands	1838	EN11 8AZ	flat	clay, silt & sand	X	built up
46	Chatsworth	1842	DE45 1PP	hillside	Chatsworth gritstone	√	built up
47	Biddulph Grange	1842	ST8 7SD	flat	mudstone, siltstone & sandstone	√	built up/excavated
48	Highnam Court	1847	GL2 8DP	undulating/boggy	mudstone	X	built up
49	Lamport Hall	1848	NN6 9HD	flat	sandstone, limestone & ironstone	√	built up
50	Osmaston Manor	1849	DE6 1LW	undulating	sandstone	√	built up
51	Welbeck Abbey	1854	S80 3LZ	undulating	mudstone + sandstone	√	underground
52	Sydnope Hall	1858	DE4 5LN	on a slope	mudstone/silstone Chatsworth grit nearby	√	built up
53	Oakworth House	1864	BD22 7PD	flat	sandstone	√	built up
54	Glen Andred	1865	TN3 9PN	rocky outcrops	sandstone	√	excavated
55	Battersea Park	1865	SW11 4NJ	flat	clay	X	built up
56	Audley End	1867	CB11 4JF	undulating	chalk	X	built up
57	Stancliffe Hall	1870	DE24 2HJ	on a hill	sandstone	√	in a quarry
58	Ascog Hall Fernery	1870	PA20 9EU	by the sea	microgabbro similar to dolerite (igneous)	√	sunken
59	Cragside	1870	NE65 7PX	steep hillside	sandstone	√	built up
60	Brodsworth Hall	1870	DN5 7XJ	flat/undulating	magnesian limestone (dolostone)	√	in quarry
61	St Fagans Castle	1872	CF5 6XB	in a valley	limestone + mudstone interbedded	√	built up
62	Swiss Garden	1876	SG118 9EP	flat	mudstone w sandstone nearby	√	sunken
63	St Albans Court	1877	CT15 4HH	hollow	chalk	X	sunken
64	Highbury Park	1878	B13 8QG	hilly	sandstone	√	sunken/built up
65	Waddesdon Manor	1881	HP18 0JH	valley between hills	sandstone + limestone	√	built up
66	Kew Gardens	1882	TW9 3AE	flat	sand and gravel	X	excavated/built up
67	Warley Place	1882	CM13 3HT	flat	clay & silt	X	excavated
68	Sheffield Park	1882	TN22 3QX	undulating	sandstone & siltstone	√	built up

Table 3 continued

No	Name	Dates	Postcode	Original topology	BGS bedrock	Suitable?	Type of rockwork features
69	Munstead Wood	1883	GU7 1UN	flat	sandstone & mudstone	√	sunken
70	East Park	1887	HU8 8JU	flat	clay & silt over chalk	X	built up
71	The Dell	1888	TW20 0JW	on a hill	sand	X	built up
72	Ewell Court House	1892	KT19 0EB	undulating	clay & silt	X	built up
73	Madiera Walk	1894	CT11 8LT	hillside	mudstone + limestone nearby	√	built up
74	Dewstow	1895	NP26 5AH	flat	mudstone (silt & clay)	X	underground
75	Wotton House	1896	RH5 6HS	sloping	clay	X	built up
76	Grove House	1897	SW15 5PJ	gentle slope	chalk	X	bult up
77	Friar Park	1898	RG9 4NR	sloping	chert/ limestone nearby	√	built up/underground
78	Aysgarth rock garden	1906	DL8 3AH	flat	siltstone + sandstone	√	built up
79	Merrow Grange	1907	GU1 2QU	undulating	sand	X	built up/underground
80	Gatton Park	1910	RH2 0TW	sloping	siltstone + sandstone	√	built up
81	RHS Wisley	1911	GU23 6QB	steep sloping	Bagshot formation - sand	X	excavated/built up

Table 4: Chosen rock type(s)

No	Name	Dates	Chosen rock(s)	Imported?	Distance transported
1	Bushy Park	1710	unknown	yes	unknown
2	Popes grotto	1720	spngestone + many others	yes, UK and overseas	>100 miles
3	The Gnoll	1730	sandstone + limestone		
4	Prior Park	1734	Bathstone (limestone)+ spongestone		
5	Stowe	1738	limestone		
6	Goldney	1739	sandstone; Brandon Hill Grit	yes	>50 miles
7	Belton	1740	unknown	yes	unknown
8	Leasowes	1743	sandstone		
9	Warmley House	1746	sandstone		
10	Hagley	1747	sandstone		
11	Stourhead	1748	spongestone + volcanic rocks	volcanic rocks, Italy	>200 miles
12	Hackfall	1749	sandstone + real tufa		
13	Hawstone	1750	red sandstone		
14	Enville	1750	sandstone, quartzite, slag		
16	Claremont	1750	sandstone; granite	yes	
16	Virginia Water	1753	Heath stone - sandstone or saxon building stone	yes	<10 miles
17	Halswell Park	1754	limestone/reclaimed building stone		
18	Plumpton Rocks	1755	millstone grit		
19	Painshill	1760	spongestone + tufa	yes	
20	Croome Court	1760	Bathstone/spongestone	yes	
21	Oatlands	1762	spongestone	yes	
22	Rokeby	1769	limestone		
23	Scotts grotto	1770	chalk		
24	Chelsea Physic Garden	1773	collection	yes, Iceland	>200 miles
25	Badger Dingle	1780	red sandstone		
26	Haford	1780	sandstone; mudstone interbedded		
27	Ascot Place	1780	slag + flint, + tufa	yes	
28	Quarry Bank	1784	sandstone		
29	Bowood	1785	sandstone		
30	Thoresby	1791	limestone	yes, Creswell Crags	few miles
31	Wardour Castle	1792	spongestone	yes	
32	Fonthill	1794	limestone		

Table 4 continued

No	Name	Dates	Chosen rock(s)	Imported?	Distance transported
33	Swinton	1800	limestone		
34	Sezincote	1800	sandstone		
35	Coleorton Hall	1802	sandstone + builders' rubble		
36	Kidbrooke Park	1803	sandstone		
37	Belsay Hall	1806	sandstone; ironstone		
38	Redleaf House	1807	red sandstone		
39	Hewell Grange	1812	red sandstone		
40	Basingill	1821	limestone		
41	Hoole House	1826	red sandstone + limestone	yes, Wales	<100 miles
42	Syon Park	1830	granite	yes	~200 miles
43	Pencarrow	1831	granite	yes Bodmin Moor	10-15 miles
44	Elvaston Castle	1838	sandstone + tufa	yes	great distance'
45	Woodlands	1838	pulhamite	made on site	
46	Chatsworth	1842	gritstone		<1 mile
47	Biddulph Grange	1842	Chatsworth gritsone		~1 mile
48	Highnam Court	1847	Yorkstone (sandstone) + Pulhamite	yes	~200 miles
49	Lamport Hall	1848	ironstone; red sandstone		
50	Osmaston Manor	1849	limestone	yes	10 miles
51	Welbeck Abbey	1854	limestone + pulhamite	yes, Creswell Crags	~1 mile
52	Sydnope Hall	1858	gritstone		
53	Oakworth House	1864	sandstone & concrete		
54	Glen Andred	1865	sandstone		
55	Battersea Park	1865	artifical pulhamite	made on site	
56	Audley End	1867	artifical pulhamite	made on site	
57	Stancliffe Hall	1870	millstone grit	Balladon Moor	10 miles
58	Ascog Hall	1870	red sandstone rubble	from sea-shore	<1 mile
59	Cragside	1870	sandstone	moors on estate	~1 mile
60	Brodsworth Hall	1870	magnesian limestone		
61	St Fagans Castle	1872	limestone + pulhamite		
62	Swiss Garden	1876	faux tufa (pulhamite)	made on site	
63	St Albans Court	1877	Wealden sandstone	yes, Maidstone	~38 miles
64	Highbury Park	1878	sandstone		

Table 4 continued

No	Name	Dates	Chosen rock(s)	Imported?	Distance transported
65	Waddesdon Manor	1881	limestone	yes, Gloucester	~70 miles
66	Kew Gardens	1882	Bath oolite + limestone+ marble	yes, Cheddar	>100 miles
67	Warley Place	1882	millstone grit	yes, Yorkshire	>200 miles
68	Sheffield Park	1882	sandstone	local quarries	<10 miles
69	Munstead Wood	1883	sandstone + other		
70	East Park	1887	sandstone	yes, Leeds	~85 miles
71	The Dell	1888	artificial pulhamite	made on site	
72	Ewell Court House	1892	artificial pulhamite	made on site	
73	Madiera Walk	1894	artificial pulhamite	made on site	
74	Dewstow	1895	limestone + pulhamite+ real tufa	yes, Ifton quarries	<2 miles
75	Wotton House	1896	sandstone + pulhamite	local, made on site	
76	Grove House	1897	natural + artifical (Harpham)		
77	Friar Park	1898	millstone grit; artifical tufa	yes, Yorkshire	>200 miles
78	Aysgarth rock garden	1906	limestone	Stephen's moor	<1 mile
79	Merrow Grange	1907	sandstone + pulhamite + tufa	tufa, Glocs or Derbyshire	>100 miles
80	Gatton Park	1910	Yorkstone+ ragstone+pulhamite		
81	RHS Wisley	1911	Surrey sandstone	yes	~14 miles

Table 5: Construction related exemplars

No.	Name	Dates	Procurement	Transport	Design	Excavation	Construction	Water management	Final fix decoration	Specific techniques	Tools equipment
1	Bushy Park	1710	imported		illusion		fixing	re-routed river 2K of culvert	paintings mortar	lime mortar	
2	Popes grotto	1720	contacts	sea; river	underground illusion		brick core, vaulted pillar & stall	spring gravity feed	collection	lime mortar cramps	camera obscura
3	The Gnoll	1730	local		industrial			leats pipes, culvert	shells	stalactites	
4	Prior Park	1734	local quarries	railway; tramway	illusion		unusual floor	wooden pipes connections	shells		
5	Stowe	1738			architectural political	earth-moving volume	lake lined with copper	feeder lake on/off	shells		
6	Goldney grotto	1739	local contacts		illusion		tiled floor	pumped supply from well	collection	stalactites	early steam engine
7	Belton	1740	imported		early picturesque cascade			dual use sluice			
8	Leasowes	1743	local		circuit			springs, gravity fed turning on/off	cinders/pebbles		camera obscura
9	Warmley House	1746	recycling		industrial		vaulted lanterns	dammed brook pumped feed	no decoration		early steam engine
10	Hagley	1747	furnace slag	sea; river	circuit illusion			springs, gravity fed, culverts	shells/spar		
11	Stourhead	1748			Pyper 3-D model	foundation	lighting	springs stone conduits	spars		water pump
12	Hackfall	1749	local		picturesque	earth-moving		streams, collection pools, wooden	tufa no decoration		hand pump
13	Hawstone	1750	furnace slag		embellished rocks		pillar & stall no lighting	No natural water lake added 1784		chisel marks	
14	Enville	1750	slag		circuit		vaulted	holding pond turning on/off		exciter bricks rock cutting	
16	Claremont	1750	imported	river; road	cave-grotto			spring fed lake	spar/mica		
16	Virginia Water	1753	imported	road	Sandby painting	large scale preparatory work	gunpowder	drainage lake dam	no decoration	reducing rock size	
17	Halswell Park	1754	building remains		illusion		mortar and cramps	six lakes gravity fed	no decoration	cramps	
18	Plumpton Rocks	1755	rocky outcrops		embellished rocks			dammed lake		chisel marks rock cutting	
19	Painshill	1760	bricks		Pyper drawings		brick core, metal rods, timber beams	pumped supply	spar/ tufa/ slag	stalactites	waterwheel archimedes screw
20	Croome Court	1760	imported	Newman paid for transport	rusticated grotto	foundations found	double-walled structure	wooden pipes reservoir/ culvert	spar/ shells	drain within grotto	
21	Oatlands	1762	scull iron		original plan/3-D model		pitched roof, floor, lighting	spring fed lead pipes	shels/ spars/ tufa	cramps stalactites	tool lists
22	Rokeby	1769	existing on site		embellished rocks		revetment wall to river	confluence of 2 rivers	no decoration	chisel marks rock cutting	
23	Scotts grotto	1770	melted glass		underground grotto	use of spoil	pebble floor, lanterns, ventilation		shells/spar		pickaxe

Table 5 continued

No.	Name	Dates	Procurement	Transport	Design	Excavation	Construction	Water management	Final fix decoration	Specific techniques	Tools equipment
24	Chelsea Physic Garden	1773	old buildings contacts	sea/river	collection			pond	collection		
25	Badger Dingle	1780	existing on site		embellished rocks water	volume	excavation burst dam	dammed stream		cutting thro' rock	
26	Haford	1780	local		sublime embellished			river		cutting thro' rock	
27	Ascot Place	1780	furnace slag		rusticated grotto		brick core , lighting pebble floor	lake	spars	lime mortar	laser scanning restoration
28	Quarry Bank	1784	local		industrial			waterwheel	no decoration		
29	Bowood	1785	local		original plan			lake overflow pipework	no decoration		
30	Thoresby	1791	Cresswell Crags	road/track	naturalistic cascade	excavation		lead pipes		exciter stones	
31	Wardour Castle	1792	building remains		primitive grotto				shells/ tufa		
32	Fonthill	1794	local quarries		primitive grotto	excavation	lighting	dammed stream channels in grotto	no decoration	stalatites	waterwheels
33	Swinton	1800	local	road	scattered rockwork	excavation spoil for roads	lintel	dammed lakes	no decoration		
34	Sezincote	1800	local limestone		Indian pictureque		grotto square plan	stream	no decoration	rocky embankment	
35	Coleorton Hall	1802		road	plan + description		pebble floor		shells/ tufa		early waggonway
36	Kidbrooke Park	1803	local sandstone		naturalistic Repton sketch			culverts chalybeate spring		stone-lined stream	
37	Belsay Hall	1806	local		within quarry		accuracy of build		planting	chisel marks	
38	Redleaf House	1807	on-site red sandstone		quarry drawings	excavated + built-up		altered river line			pump in engine house
39	Hewell Grange	1812	local	canal	quarry garden			water tower sluice		balancing stone	
40	Basingill	1821	local limestone		industrial picturesque		revetted quarry face				waterwheels
41	Hoole House	1826	imported from Wales		3-D model	weather issues	problem wall			retaining wall	1st use of gunmetal
42	Syon Park	1830	imported	sea/ river	contrast					embankment	
43	Pencarrow	1831	local stone moors	road/ track	imitation of nature	use of spoil			no decoration	embankment	
44	Elvaston Castle	1838	imported	river	scattered rockwork	use of spoil		water tower dual use	tufa	making larger rocks	
45	Woodlands	1838	artificial		hiding a view		Roman cement	dammed stream		working with pulhamite	
46	Chatsworth	1842	local stone		imitation of nature	volume	cementing stones together	gravity feed, pipes, taps/ valves		machinery balance stone	

Table 5 continued

No.	Name	Dates	Procurement	Transport	Design	Excavation	Construction	Water management	Final fix decoration	Specific techniques	Tools equipment
47	Biddulph Grange	1842	local	railway tramway	models		involvement of Cooke + Bateman	drainage pipe	collection		
48	Highnam Court	1847	imported & artifical		trail + error hiding view		experimental brick core	springs silt traps, pipes	no decoration	retaining wall	
49	Lamport Hall	1848	local		rockwork near house		built to face the house			no lifting devices; chisel marks	
50	Osmaston Manor	1849	local		trail + error	excavated dell	problem	cast-iron pipes dual use		early use of ashfalt	waterwheel tramway
51	Welbeck Abbey	1854	local & artificial	road; track	scale model (house)	excavation of solid clay	cut & cover lanterns	concreted lake			traction engine
52	Sydnope Hall	1858	local		natural style				no decoration		hydraulic engine
53	Oakworth House	1864	local		illusion		tiled floor	three reservoirs	concrete rustic work	stalactites	
54	Glen Andred	1865	rocky outcrops		embellished rocks	blasting				strategies for lifting	wire probe
55	Battersea Park	1865	artificial		hiding a view			pumped feed from river			steam engine
56	Audley End	1867	pebbles + artificial		cold fernery		iron framework	sluice, tap	ferns		
57	Stancliffe Hall	1870	quarry		quarry garden	cliff excavated explosives				blasting	
58	Ascog Hall Fernery	1870	local		sunken fernery			spring fed			
59	Cragside	1870	moors	temp roads	scattered rockwork		concrete along watercourse	hydraulics; ceramic pipes; sluice; tap		strategies for lifting	levers; block & tackle; crane
60	Brodsworth Hall	1870	local	railway	quarry garden	subsidence					
61	St Fagans Castle	1872	local & artificial		Pulham plan			spring fed ponds sluice/culverts			
62	Swiss Garden	1876	artificial		picturesque fernery/grotto	excavation embankments		local river dammed	faux tufa	faux stalactites	restoration tools
63	St Albans Court	1877	imported	railway; road	sunken garden	excavated					
64	Highbury Park	1878	local		rockwork as framework						
65	Waddesdon Manor	1881	local & imported	railway	unadorned grottos	volume/problems	brickwork core	mains water 7 miles of pipe	no decoration	working with pulhamite	traction engines traditional tools
66	Kew Gardens	1882	imported		imitation of nature	use of spoil	excavation needed rebuild	river Thames pumped		making paths wedges	
67	Warley Place	1882	contractor	railway	alpine garden	excavating a gorge		ponds reservoirs			
68	Sheffield Park	1882	local	railway	water garden	volume	excavation puddling	pumped feed ceramic pipes;		pulhamite exciter bricks	hydraulic ram
69	Munstead Wood	1883	local		sunken rock garden	excavated					

Table 5 continued

No.	Name	Dates	Procurement	Transport	Design	Excavation	Construction	Water management	Final fix decoration	Specific techniques	Tools equipment
70	East Park	1887	clinker		model Khyber Pass						
71	The Dell	1888	artificial		rocky outcrops			water tower pumped feed			
72	Ewell Court House	1892	artificial		fern grotto			pipework	ferns		waterwheels
73	Madiera Walk	1894	artificial		Pulham plan; contract			pumped system		pulhamite rocks made offsite	
74	Dewstow	1895	local & artificial		underground grottos		cut & cover lanterns	mains water connections	no decoration	colouring agents hessian sacks	
75	Wotton House	1896	local & artificial		fernery/grotto		earth roof mica in cement	stream with sluice tap in fernery	no decoration	framework stalactites	
76	Grove House	1897	local & artificial		sham bridge illusion			spring filled lake	no decoration		
77	Friar Park	1898	clinker contractor	railway	moveable model illusion	excavation to form valley + underland	trial and error	mains water		balancing stone	basic lifting equipment
78	Aysgarth rock garden	1906	moors	road	walk-through grotto		lintel lime mortar	spring header tank	no decoration	lintels lining ponds	crane
79	Merrow Grange	1907	imported & artifical		sunken fernery	use of spoil	3-d effect of mountain skyline		mica		
80	Gatton Park	1910	local & artificial		rock & water garden			pumped feed turning on/off	planting		hydraulic ram
81	RHS Wisley	1911	imported stone	road; tramways	no plans changes made	trial holes hand excavation	maintenance issues	well; petrol pump; dual use	alpine planting	land drains concrete/valves	traditional tools

Appendix 2

Glossary of technical terms

Bagshot formation – sand – a geological term for the sandy layer over clay found in the London and Hampshire basins. Named after Bagshot Heath in Surrey.

Balancing stone - a naturally occurring geological formation featuring a large rock or boulder, sometimes of substantial size, resting on other rocks. They can often be moved easily and return to their balanced position. An example is the Logan Rock in Cornwall.

Bathstone – oolitic limestone from Bath region. Chemically formed limestone composed of minute spherical egg-like grains of calcium carbonate – looks like caviar or fish roe.

Bell pit – a primitive method of mining coal, iron ore or other minerals where the coal or ore lies near the surface. The shape of the excavation represents a bell-shape.

Bessemer's steel process – the first inexpensive industrial process for the mass production of steel from molten pig iron. Invented in 1850s.

Block and tackle - a system of two or more pulleys with a rope or cable threaded between them, usually used to lift heavy loads. The pulleys are assembled together to form blocks and then blocks are paired so that one is fixed and one moves with the load.

Blue John - another word for Derbyshire fluorspar – a semi-precious gemstone mineral. A form of fluorite with bands of purple-blue or yellowish colour, found only in Derbyshire.

Cast iron and wrought iron - cast iron is made from re-melting and refining pig iron and cast in moulds. Used from 1790s until c1870 for decorative ironwork ,also beams and roof rafters, replacing wood. Wrought iron is made by removing impurities from pig-iron and rolling. Used from 1850s onward for columns, I-shaped girders. Both were replaced by steel from 1900.

Circumferentor - a pre-cursor to the theodolite which measured bearings rather than angles and looked like a large compass mounted on a tripod.

Clinker – stony residue from burnt coal or from a furnace.

Clinker brick – a brick with a vitrified surface, formed from being too close to the furnace ie burnt.

Combustion engine – one where fuel (petrol or diesel) is burned within the engine proper, rather than in an external furnace as in a steam engine.

Concrete – made from cement and aggregate.

Conduit – a channel or pipe for conveying water.

Corve – a wicker basket or mine cart used to haul material from the coalface to the shaft. Also known as a 'tub'.

Cramps – bent pieces of iron, in the shape of a staple, to secure stones which might be prone to movement or displacement. Commonly use in building construction.

Crowbar – a heavy iron bar with a bent end that is used to help lift heavy objects off the ground or to force things open. See also gavelock.

Culvert – a tunnel carrying a stream or drain under a road, house or similar obstruction.

Cut and cover - the oldest method of tunnelling. The basic concept involves excavating the area, constructing the core tunnel in the excavated area, and then returning the excavated area to its original state.

Derrick crane – a type of crane capable of lifting a load as well as swinging the load horizontally.

Fire engines – name given to early steam driven beam engines.

Fluorite or Fluorspar (calcium fluoride) – cuboid crystals with greenish tinge, from Derbyshire.

Gavelock – a straight iron crowbar or lever

Granite - an igneous rock mostly composed of two minerals: quartz and feldspar. It is crystallized from magma that cooled below the Earth's surface.

Gritstone (Brandon Hill Grit) - referred to on geological maps as Quartzitic Sandstone and considered as a local equivalent of Millstone Grit Series (in northern England) – deep red colour with pinkish quartzite inclusions; weathers extremely well.

Groin vault and barrel vault – a barrel vault is a type of ceiling composed of a series of semi-cylindrical arches. A groin vault, also known as a double barrel vault, is a ceiling produced by a series of intersections at right angles of two barrel vaults.

Hawk – a tool used to hold mortar or similar material. Consists of a square board with a perpendicular handle on the reverse. The plasterer holds the hawk horizontally and applies the material with a trowel or float in the other hand.

Horse and gin – a basic horse-engine (gin is short for 'engine) where the horse walks around in circles often for raising or lowering heavy items or turning a mill. Like a treadmill but horizontal rather than vertical.

Hydraulic crane – type of crane invented by William Armstrong using the concept of transmitting forces from point to point through a fluid.

Hydraulic ram pump – a pump powered by hydropower. It takes in water at one level and flow-rate and discharges water at a higher level and lower flow-rate. The only moving parts are valves so it is mostly maintenance-free.

Inclined plane – a form of cable railway to move vehicles on a steeply graded line; one of six different simple machines used to raise a load

Jack – a portable device for raising or lifting heavy objects. Can operate by turning a handle or using hydraulic or pneumatic power

Jib – the projecting arm of a crane, can usually rotate around the crane tower and move up and down.

Kynance stone – a serpentine rock found in Kynance Bay, Cornwall.

Lanterns - roof-lights often glazed, also called light wells.

Leat – the name for an artificial watercourse or aqueduct dug into the ground, especially one supplying water to a water mill or its pond.

Lever - a rigid bar resting on a pivot, used to move a heavy or firmly fixed load with one end when pressure is applied to the other.

Lewis – a device for gripping heavy blocks of stone for lifting by crane.

Lime mortar - is composed of lime and an aggregate such as sand, mixed with water. It is one of the oldest known types of mortar. Used for fixing bricks or stones or for covering surfaces.

Limestone – a hard sedimentary rock, composed mainly of calcium carbonate or dolomite, often used as building material and in the making of cement.

Millstone grit – a coarse, hard sandstone from the Carboniferous age, occurring immediately below the coal measures. Its name comes from its use in making millstones.

Mudstone – a fine grained sedimentary rock whose original constituents were clays or muds.

Navvies - labourers employed in the excavation and construction of a road, railway, or canal.

Newcomen steam engine – an early beam engine invented by Thomas Newcomen in 1712 powered by steam. First used for pumping water out of mines.

Petrifactions – the result of organic matter being exposed to minerals for a long time, turning it into a stony substance. Many fossils are formed in this way.

Pickaxes or crowbars - a tool for breaking hard surfaces, with a long wooden handle and a curved metal bar with a sharp point.

Pillar and stall – early mining technique where pillars of coal were left to support the roof while coal was extracted around the pillar.

Portland cement – cement manufactured from chalk and clay which hardens under water and when hard resembles Portland stone in colour.

Puddling – a method for lining lakes or ponds on permeable land to make them watertight. Puddled clay was made by removing all the air pockets, often using men or animals to repeatedly tread on it.

Pulhamite – a 19C artificial stone produced by James Pulham & Son.

Quadrant rack – a type of rack and pinion where a circular gear (the pinion) engages with a linear gear (the rack) to transform rotational motion into linear motion, usually up or down. In a quadrant rack the motion becomes rotation over part of a circle (an arc).

Quarry pick – a hand tool with a hard head attached perpendicular to the handle. Used in a quarry for making holes in a rock or shaping cut rock.

Ranging rod - a surveying instrument used for marking the position of stations, and for sightings of those stations, as well as for ranging straight lines. Initially these were made of light, thin and straight bamboo, or of well-seasoned wood such as teak, pine or deodar.

Retaining wall – a structure that retains any material, usually earth, and prevents it from sliding away or eroding. Usually made of brick or stone.

Revetment wall – a sloping wall on the banks of a river or waterway as a defence against erosion.

Ridge and furrow – the result of using medieval farming methods using a one-sided plough. The ridges gave extra soil depth and the furrows (ditches) aided field drainage.

Roman cement – a substance developed by James Parker in the 1780s. Made by burning septaria nodules which contain both clay and chalk. The burnt nodules are then ground to a fine powder and mixed with sand to make a mortar which seta very quickly.

Sandstone - sedimentary rock consisting of sand or quartz grains cemented together, typically red, yellow, or brown in colour.

Scaffixer – a coupling device holding together scaffold poles. They were much more robust than the rope that had been previously used.

Scull iron – steely waste from inside the ladle.

Sheer-legs - a device for lifting heavy weights consisting of two or more poles lashed together at the upper ends from which a lifting tackle is suspended.

Slag – brick slag or iron slag – often called cinders.

Sluice - a sliding gate or other device for controlling the flow of water.

Spar - crystalline mineral formations in rocks, often used in grotto decoration.

Spongestone – one of many names to describe the grotto rock which has the appearance of sponge or honeycomb. Always a limestone or calcareous mudstone which formed a hardground on the seabed and was burrowed into by marine organisms producing many cavities.

Surveyor's chain - a distance measuring device used by a surveyor in 18C.

Spillway - means of passing overflow water around or through a dam in a controlled way.

Standpipe – a vertical pipe connected to a water supply, usually connected to a temporary tap.

Sump – a pit or hollow in which liquid collects, often in the floor of a mine or cave.

Tarmacadam – a road surfacing material patented by Hooley in 1902. Made by spraying or pouring a tar binder over layers of crushed stone and then rolling.

Tees-Exe line – an imaginary northeast-southwest line that divides Britain into lowland (sedimentary rock) and upland regions (igneous and metamorphic rock). The line links the mouth of the river Tees in the north east with the mouth of the River Exe in Devon.

Theodolite - a surveying instrument with a rotating telescope for measuring horizontal and vertical angles.

Traction engine - a steam-powered locomotive used for drawing heavy loads along roads or over rough ground.

Tramways – an early form for railway where wagons/carriages are hauled on rails, initially wooden then iron.

Tufa – irregularly formed deposit of calcium carbonate around vegetation. Is usually associated with petrifying springs issuing from calcareous rocks.

Turnpike - a road on which a toll was collected at a toll gate.

Wagons, wains or carts – a wagon is a 4-wheeled horse-drawn vehicle; a cart has only two wheels and a wain is the old English word for a farm wagon or cart e.g. hay wain.

Wedge – one of the original simple machines, made from a triangular piece of wood, stone or metal. Used in quarries to split large pieces of rock for extraction.

Winch or windlass - a machine that lifts heavy objects by turning a chain or rope around a drum. The drum can either be horizontal or vertical.

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