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21 A small terrace cut into the slope, above and to the north of site 20. Contains a possible collapsed fireplace.

22 A small terrace cut into the slope, above and to the south of site 20. Contains a possible collapsed fireplace.

23 A terrace cut into the slope, c. 15 m long. Above a junction in the track from the bakehouse to the battery site.

24 A small terrace, cut into the slope. At the time of the survey it showed evidence of recent fossicking.

25 A terrace cut into the slope within the area of regenerating beech forest, c. 16 m long.

26 A terrace cut into the slope, c. 16 m long. Stone revetting along the down-slope edge. There is a small terrace to the south, with two small depressions (possible site of a long-drop toilet?). At the time of the survey there was evidence of recent fossicking below the site.

27 A terrace cut into the slope, adjacent to a spur that defines the edge of the Bakery Flat area. A track runs beside the site to a possible collapsed shaft site to the east.

28 A terrace cut into the slope below site 27, c. 6 m × 6 m.

29 A terrace cut into the slope below site 28.

30 A terrace cut into the slope below site 29. Contains the remains of some timber framing, some corrugated iron and an iron bedstead. At the time of the survey there was evidence of recent fossicking.

31 The remains of a corrugated iron clad structure on a small terrace immediately to the north of the New Main Shaft winding house site. One corner of the structure was still standing in 1996.

The above building sites are to the north of a sharp spur that runs down towards Murdochs Creek. Several tracks run from this area around towards the Phoenix Battery site and further building sites. An unstable open area of ground crosses these tracks in line with the entrances to the Adit and No. 3 Levels of the mine. The building sites discussed below are on the south side of the spur.

Figure 38. Phoenix Hotel site, similar view to Fig. 37. *Photo: P. Petchey.*

32 A terrace cut into the slope, c. 37 m × 5 m. There was a portion of standing corrugated iron in the middle of the terrace, and more sheets of iron were scattered about the terrace.

33 A terrace cut into the slope east of site 32.

34 A terrace cut into the slope at a point where the gradient eases. Some distance above site 33. There was a concentration of corrugated iron on the site and scattered downslope, suggesting that this building collapsed in situ rather than being dismantled.

35 A thin terrace cut into the slope, along track from site 32.

36 A terrace cut into the slope, along a track line. Stone revetting on the upslope face.

Sites 37 and 38 are situated on a large terrace cut into the hillside around a spur above the site of the Phoenix Battery.

37 One half of angled terrace, measuring c. 50 m × 10 m. Contains the remains of a structure with corrugated iron cladding on a timber frame, with some sheet iron and brick interior lining. Possibly the remains of the mine safe. Collapsing.

38 One half of angled terrace. The location of a corrugated iron-clad building outlined by bottom sheets of iron still in situ. The structure measured 14 m × 8 m. A telegraph or power pole was situated close to the northern corner.

39 A terrace below site 37. The platform had been partially cut into the slope, and partially built up with the resultant fill, c. 12 m × 4 m.

40 A terrace cut into the slope, c. 20 m × 8 m. Stone revetment on upslope face. Contains the remains of two schist fireplaces. There was extensive evidence of fossicking on this site and on the slope below. Fragments of crucibles and insulators suggest that this might be the site of the assay office. A cast iron winding drum is sitting on the track below this site.

41 A terrace cut into the slope to the northwest of site 40. Contains the standing corner of a collapsed corrugated iron clad building and large numbers of red bricks.

The above sites (32 to 41) appear to consist of a mixture of huts and mine buildings. Site 40 was probably the site of the mine assay office, site 37 possibly the mine office with the gold safe, and site 38 was a large rectangular building, possibly mine offices, a storehouse, or Bullen Hall. It is known that Bullen Hall was lit with electric light, and a power or telegraph pole was situated beside the remains of the building on site 38. This cluster of building sites was distinct when compared with the other sites discussed above, as it contained larger structures with more evidence of industrial/commercial activity, strongly suggesting that they were associated with the mine operation rather than being individual miners' huts.

9.1.8 Caspers Flat

Caspers Flat is situated beside Skippers Creek, upstream from the Murdochs Creek confluence. The main area is a long narrow flat on the true right of the stream, with an overgrown hawthorn hedge running along the middle, together with a poplar tree and a large area of wilding mint (Figs 34 and 39). An old benched track zig-zags up Southberg Spur above the flat.

Three building sites were recorded during the 1996 survey; two on the true right bank and one on the true left.

42 A hut site on the true right bank of Skippers Creek. The stone foundations of the hut measure c. 7 m × 4 m, with a 2-m-wide extension on the west side. A stone fireplace is incorporated into the north wall, 3.4 m wide × 1.8 m high.

43 A small hut site on the true right of the creek, near the base of Southberg Spur. Some stone and iron present. Located about half way along an overgrown hawthorn hedge that runs east–west for c. 100 m along the flat.

44 The remains of a blacksmith's forge on the true left of the creek. A fallen, timber-framed, corrugated iron-clad structure containing a schist forge (52 in × 40 in, 1.32 m × 1.01 m). A large set of timber and leather bellows is sitting beside the forge (Fig. 40). Since the 1996 survey the Department of Conservation has constructed a small shelter to protect this site.

Figure 39. Caspars Flat, Skippers Creek, 1996. The line of hawthorn trees (an overgrown hedge) is clearly visible. A hut site is located near the poplar tree. *Photo: P. Petchey.*

Figure 40. Caspars Flat, wood and leather bellows at the forge, 1996. *Photo: P. Petchey.*

10. The communications infrastructure

During the life of the mine, a network of tracks was developed to link the features described above to each other and to the outside world. In addition, there was a telegraph line out to Skippers, and the power lines from the dynamos over Southberg Spur to the Phoenix Battery. Some transportation systems were essential parts of the mining operation, such as the tramway and aerial cableway on British-American Spur, and these are discussed above in sections 6.1 and 6.2.

10.1 THE BULLENDALE ROAD

As discussed in the general history above (section 4), there was no formed dray road into Bullendale. All equipment and supplies for the mine had to be transported up the creek bed and via a narrow pack track winding along the valley sides where the bed was impassable. Although a legal road line exists, much of it has never been formally surveyed. A search of documents at the Department of Survey and Land Information (now Land Information New Zealand) in Dunedin failed to find any record of a formal survey. The road line shown on cadastral maps appears to be the pack track simply sketched in.

This pack track was probably first constructed in about 1864 or 1865 when the first heavy machinery was being taken into the area. It is likely that the track followed the stream bed except for two sections: one between Fergusons Creek and Jennings Creek, which is extremely rough; and the section of Skippers Creek by the confluence with the Roaring Meg, where the stream runs in a small gorge.

Two alternative tracks were constructed in this area. One track was cut into the side of the gorge on the true right bank, with several sections supported by dry stone wall revetment. This track climbs over the very narrow crevice that the stream has cut, but there are several obstacles further upstream that make its use difficult if carrying much weight. The other track was constructed on the true left of the stream, and follows the route shown on maps of the area. It climbs high above the gorge section of Skippers Creek, and avoids a number of other difficult sections of the bed. It is considerably longer than the direct route along the creek, but would have been safer and easier for the transport of heavy mining equipment. The track was almost certainly formed prior to 1866, as it appears on a topographical map of Skippers Creek District dated June 1866.

In 1949, the Lake County Council made a small grant to repair some of the track to allow the transport of a 3-stamp battery to Copper Creek[17], but in 1959 when R.F. Woodbury made a request for similar assistance, it was turned down. The Under Secretary of Mines at the time commented that ‘in the past there never has been any other access except for a pack track, even when mining was at its peak’ (Under Secretary of Mines, letter to R.F. Woodbury, 21 Oct 1959, Mines Department Dunedin, File 12/46/1187).

[17] This would not have included the section of track climbing past the Roaring Meg confluence, as the track to Copper Creek went up the Left Branch of Skippers Creek past the dynamos.

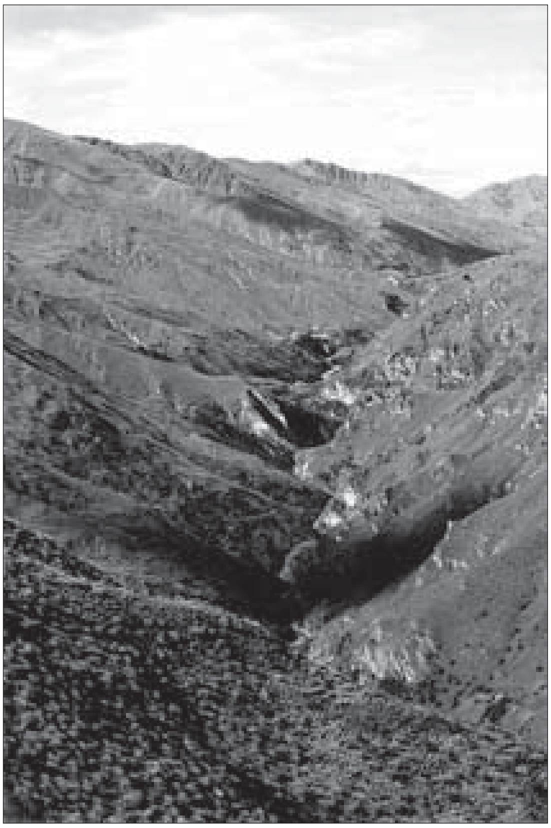

Figure 41. View looking down Skippers Creek from British-American Spur. The Bullendale Road can be seen winding along the hillside on the left of the creek. The difficulties in transporting heavy mining equipment in this type of country can be readily imagined.
Photo: P. Petchey.

In the 1950s or 1960s, K. Sarginson of Mount Aurum Station put in a new farm track across the Roaring Meg, following a slightly different line to the old pack track. From the air both tracks are visible, crossing in places, although only the newer track is easily discernable when on the ground. The new track was maintained until the late 1960s, but has been impassable to four-wheel-drive vehicles since then (J. Sarginson, pers. comm. 1996; P. Mason, pers. comm. 1996). Figure 41 shows the road winding along the hillside above Skippers Creek.

Therefore, the section of the walking track past the Roaring Meg that is generally followed to reach Bullendale today only dates from the 1950s, although the legal road line dates from the mid-1860s. The two follow slightly different routes. This is an important distinction, as pressure to reopen the Bullendale road by mining and four-wheel-drive recreational interests in the late 1990s hinged on the existence of a legal road line. The Department of Conservation and other interested parties opposed allowing vehicular access, not least because of fears of increased fossicking and theft of historic artefacts (*Otago Daily Times*, 5 Sep 1996: 15; *The Mirror*, 29 May 1996: 5). Experience at the historic site of Macetown has shown that recreational four-wheel-drive access is inevitably accompanied by gratuitous damage and theft (for example, see *Otago Daily Times*, 15 Dec 2003: 25). At the time of writing (2005) there is still no formed vehicle access to Bullendale, although off-road motorcycles have been used to reach the site[18].

10.2 THE TELEPHONE LINES

There were two telephone lines at Bullendale: one to the dynamos; and one to Skippers Point, where it met the Government line from Queenstown.

A telephone line was necessary between the battery and the dynamo power house to allow the attendants at either end to communicate (AJHR 1887 C5: 47). The telephone line utilised the same power poles as the power lines across Southberg Spur. Contemporary photographs and surviving cross-members found on the spur show that there were four cables carried by the power poles: two for power and two for the telephone line. None of the power poles still stand to full height, but several short timber posts with bolt holes and discarded timber cross-members on the spur suggest that tubular steel poles may have been used, bolted to the timber posts (A. Williams, pers. comm. 2005). Just visible in the photograph of the electric motor in the battery house (Fig. 5) is a three-box Blake-type telephone. This type was not used by the Post Office in New Zealand, so it was probably privately installed for the power house link (A. Williams, pers. comm. 2005).

18 The author has seen motorcycle tracks along Skippers Creek as far upstream as the site of the Phoenix Hotel.

Figure 42. Telephone pole and insulator on the telephone line out to Skippers from Bullendale, 1996.
Photo: P. Petchey.

The telephone line to Skippers Point ran along Skippers Creek, the 5-mile-long line being installed in 1896 at a cost of £27 (AJHR 1887 C5: 47; De La Mare 1993: 35). Several iron telephone poles can still be seen on tops of spurs and outcrops along the true right bank of Skippers Creek downstream of Bullendale. At the time of the survey, only one of these still had its original white porcelain insulator in place (Fig. 42), and this was removed to the Department of Conservation office in Queenstown.

The Government line to Skippers from Queenstown had been established in 1883, and in 2005 could still be seen, as many of the telegraph poles were reused railway irons, and have survived well (although the telegraph lines themselves are no longer in place). One pole that was examined in 2001 was embossed with a manufacture date of 1878 (Petchey 2001: Plate 37).

10.3 THE SOUTHBERG SPUR TRACK

This benched track can still be seen zig-zagging up the side of Southberg Spur from Caspers Flat. On the south side of the spur two branches descend the hillside, one initially running east and one west. Both were followed during the survey, but were ultimately lost. The track that initially led to the west from the crest of the spur was followed for some distance, but ended in a steep gully, with no obvious sign of a continuation on the other side or below. The south side of Southberg Spur is covered in beech forest, so it was not possible to use aerial photographs to map the tracks.

The track up and over the spur was probably constructed to provide access to the power line that also ran over the spur, and to provide an alternative route to the power house beside the left branch of Skippers Creek.

11. Bullendale and early hydroelectrical plants

The decision to install electric motive power at the Phoenix Mine was made in late 1884, and the equipment was test run in early 1886. By this date electricity was no longer a new phenomenon, and was emerging as an efficient power source. Pioneering work had been carried out in Britain, Europe and America, and by the mid-1880s electric power stations were beginning to be built to supply lighting.

Telegraphy was the first commercial use of electricity, with Morse telegraph systems in use in the United States by the late 1840s. This technology had been made possible by the invention of the voltaic pile (the electric battery) by Alessandro Volta in 1800 (Encyclopaedia Britannica 1957: 883–4). But the voltaic pile could not provide a sustained high current, such as that required to reliably operate arc lamps (the only form of electric lighting prior to the late 1870s).

In November 1831, Michael Faraday had read a paper before the Royal Society announcing the discovery of electromagnetic induction (Singer et al. 1958: 179). The development of reliable electric generators[19] was then a process of gradual improvements, although some important steps such as the use of electromagnetic field magnets rather than permanent field magnets still had to be made (Bracegirdle 1973: 126). Generators capable of producing useful outputs began to be produced from about the 1850s, but it was Zénobe Théophile Gramme of Belgium that developed the first practical dynamo capable of producing a reliable continuous current in the early 1870s (Singer et al. 1958: 188). The Siemens company in Germany was also working on improved dynamos, and Siemens equipment was used in a number of pioneering electrical plants in Britain.

Steam engines were used to drive many of the early generators, but these had a number of drawbacks, including the slow speed of the drive and difficulties in governing that speed (Singer et al. 1958: 134). These problems were overcome by the development of high-speed reciprocating engines, such as those used by T.A. Edison in the first central electric power station in New York in 1881 (Singer et al. 1958: 133) and, more lastingly, by the first efficient steam-turbine that was patented in 1884 by Charles Parsons in Britain, designed specifically for electric generation (Bracegirdle 1973: 122, 129; Singer et al. 1958:138–9).

An obvious alternative candidate for electrical generation was water power. Work on water wheel design by engineers such as John Smeaton and Sir William Fairbairn during the Industrial Revolution (c. 1760–1830) had produced an efficient and powerful industrial power source, but one that was geographically tied to suitable water supplies (Petchey 1996: 22–27). Electricity provided a means of utilising suitable power generation sites, while still allowing a considerable degree of freedom of location for the end use. With the development of increasingly efficient high speed water turbines, hydroelectric power was a practical proposition by the late 1870s.

[19] 'Generator' is a generic term for equipment used to produce electric power. A 'dynamo' is a generator that produces direct current (D.C.), while an 'alternator' produces alternating current (A.C.).

The first known hydroelectric power station in Britain was built at Cragside, the home of Sir William Armstrong, in Northumberland in 1878 (Trinder 1992: 36)[20]. The Debdon Burn was dammed to form a storage lake, and the power house contained a 6-h.p. Thomson Vortex turbine linked to a Siemens dynamo, supplying an arc lamp in the picture gallery in the house. A small Siemens dynamo was also used as a motor in the estate's joiner's shop[21]. The power supply quickly proved insufficient for the growing needs of the house, and a second power plant was built nearby at Burnfoot Lodge in 1885 (Truman 1994).

The first public supply in Britain was probably that built at Godalming in 1881, designed to run arc lamps at a local mill and in the town streets. The equipment was installed and run by the Siemens Company, and was driven by a water wheel on the River Wey (Bracegirdle 1973: 126; www.godalming-museum.org.uk/history/electricity.htm). In Australia, the Mt Bischoff Tin Mining Company installed a Swann's Electric Light direct current dynamo in 1883, which was driven off the main water wheel shaft in the mill. This powered lights in the mill, workshops, offices and store, together with the mine manager's house and a local church (K. Montague, pers. comm. 2005).

As the above examples attest, the early use of electricity (apart from telegraphy) was mainly for lighting, although an electric motor was used in the joiner's shop at Cragside in 1878, and electroplating was another early commercial application. Early lighting installations, such as that at the South Foreland lighthouse in 1858, used arc lamps, practical incandescent lamps not being produced until about 1878 (Singer et al. 1958: 183, 214). The use of electricity for motive power only became commercially possible once practical electric motors were developed in Europe in the 1870s (Singer et al. 1958: 231).

The first public electric railway was probably that at Lichterfelde in Germany, constructed by Siemens & Halske in 1881 (Singer et al. 1958: 233). In 1883 in Northern Ireland, the Giant's Causeway, Portrush and Bush Valley Tramway Company opened a hydroelectric-powered tramway from Portrush to Bushmills. Power was generated at the Salmon Leap power station at the Walkmill Falls, which housed two Alcott water turbines driving a Siemens generator (Trinder 1992: 584; www.northantrim.com/portrush4.htm). In the same year that the Portrush railway opened, Magnus Volk opened a short, narrow-gauge electric railway along the sea-front at Brighton in England. Power was supplied by a 2-h.p. gas engine driving a Siemans D5 50 volt D.C. generator, that was replaced the following year with a more powerful engine and generator (Trinder 1992: 230; www.whitstablepier.com/volks/History.htm).

[20] It seems likely that the first hydroelectric power stations were probably in Europe, as the development of efficient water turbines and electrical equipment both largely took place there. The use of Siemens equipment in many of the early British power stations suggests that this plant was commercially available, and therefore probably in use in its home country. That information is more readily available on British power stations is probably partly a product of using English-language texts, and partly the result of the early development of interest in Industrial Archaeology in Britain during the 1970s.

[21] Early dynamos were extremely similar to motors, and could be used for either purpose.

11.1 ELECTRICITY IN NEW ZEALAND

Electric lighting had first been seen in New Zealand as early as 1879 when a jeweller's shop window on Lambton Quay in Wellington was illuminated (Smith 2001: 203). The Roslyn Mill in Dunedin was lit by electric light in 1882 (Smith 2001: 203). In May 1883 the Lyttleton Harbour Board illuminated its quay using equipment promoted by Sir Julius Vogel and Walter Prince (Chandler & Hall 1986: 144; Smith 2001: 203), and in October 1885 the Mosgiel Woollen Mills lit its carding and spinning rooms with 112 electric light bulbs (Chandler & Hall 1986: 144).

At Bullendale, a small lighting dynamo was in use in 1884 (*Lake Wakatip Mail*, 5 Dec 1884: 2), but the decision to install a large power plant was a great leap. Practical D.C. electric motors and dynamos had only been developed in the 1870s (Chandler & Hall 1986: 2; Singer et al. 1958: 231), and this was to be the first installation of its kind in New Zealand and, possibly, in the Southern Hemisphere. As such, there was a great deal of interest in the plant and its performance, and it was described in detail in a number of contemporary mining reports (e.g. Handbook of New Zealand Mines 1887: 53–54). The Phoenix Company was advised by Walter Prince, who also advised the Lyttleton Harbour Board and the town of Reefton on electric lighting supply. As has been discussed above (section 4), the two Brush Corporation dynamos and the Brush Corporation Victoria electric motor were first run in February 1886, but many problems were encountered. As the Mines Inspector said: 'very little is yet really known about electricity' (AJHR 1887 C5: 47). A number of modifications and fine-tuning improved the performance of the dynamos, and they continued in use for about 15 years.

In 1899 or 1900, two new electric motors were purchased. How old-fashioned and worn-out the original 1885/86 motor was can be seen in its relative value: the 1903 inventory of equipment at the mine listed the new motors at £664, but the old motor at only £60[22] (Hocken Library, ms 1270, 3-3-8). One problem with being at the forefront of technological development is that hugely expensive, state-of-the-art plant quickly becomes obsolete. The total cost of installing the original electrical plant at Bullendale was estimated at £5,000, of which the cost of the equipment itself was £2,190 (AJHR 1887 C5: 47).

By the time the main underground mine at Bullendale closed in 1901, the state of knowledge had increased markedly, and numerous power stations were in operation around New Zealand. The streets of Reefton had been lit by electric light in 1888, using a Crompton dynamo driven by a water turbine fed from the Inangahua River (Thornton 1982: 144). Wellington quickly followed in the same year (Thornton 1982: 144). In the Shotover River, not far from Bullendale, the Sandhills Dredge was equipped with electric power in 1891. A small hydroelectric power house on the bank of the river contained two Brush Victoria dynamos (the same model that was in use at Bullendale as a motor), driving two identical Brush Victoria motors (dynamos run in reverse) and two arc lamps on the dredge (Chandler & Hall 1986: 71–75).

[22] This was still a lot of money in 1903.

Hydroelectric power is now a mainstay of the New Zealand electric supply network, and a number of very large generating stations have been built. While the Bullendale dynamos had a maximum combined capacity of about 54 000 W (Chandler & Hall 1986: 176), the Clyde Dam, opened in 1994 on the Clutha River, can generate 432 MW of power: it is approximately 8000 times more powerful than the Bullendale installation. Some thermal stations have even greater generation capacity: Huntley Power Station can produce 1000 MW, over 18 000 times more than Bullendale.

11.2 A.C. v. D.C.

Most of the early electrical installations discussed above supplied direct current (D.C.) electrical power. One of the main drawbacks of D.C. systems were the large transmission losses experienced when power was transmitted over any distance. The system at Bullendale experienced large losses, partially due to inefficiencies in the equipment, but largely due to line losses. It was estimated that of the 70 h.p. required to drive the dynamos, only 20 h.p. was realised at the battery house a mile and three quarters away (AJHR 1887 C5: 47). Alternating current (A.C.) could be generated and transmitted at much higher voltages, and vastly reduced line losses. By the late 1890s, A.C. power had largely triumphed over D.C. systems worldwide (Chandler & Hall 1986: 2).

11.3 INTERNATIONAL SIGNIFICANCE OF THE ARCHAEOLOGICAL REMAINS AT BULLENDALE

Bracegirdle (1973: 123) has commented that the electricity supply industry has left few early relics in comparison with other types of industrial site in Britain. This is due to the urban location of many early power stations, on sites that have subsequently been redeveloped. However, the earliest known hydroelectric plant in Britain, at Cragside, was not under such development pressures, and a substantial amount survives there. The 1878 power house (without electrical equipment) and lake were intact in the early 1990s, and one turbine and the Siemen's motor from the joiner's shop were still extant in the grounds (Truman 1994). The later Burnfoot Lodge power house of 1885 is also still standing, and is now owned by the National Trust and is open to the public. It still contains the original Thomson turbine and Crompton dynamo (Truman 1994).

In Northern Ireland, The Salmon Leap powerhouse of 1883 that supplied the Portrush to Bushmills railway still exists, but is derelict and no longer contains the generating equipment (Trinder 1992: 584). The railway closed in 1949, but has been partially restored, and was reopened in 2002 using steam and diesel locomotives. Volk's Railway at Brighton has been in continuous operation since it opened (apart from wartime closure between 1940 and 1945), but electricity is now supplied by the National Grid. An early hydroelectric power scheme at the Gara River in Australia that was built in 1895 has been recorded by Gojak (1988: 3–11), but although the line of the water flume can be traced, nothing remains of the generating equipment.

In the context of these sites, the surviving 1885–86 Bullendale equipment in New Zealand is remarkably early. It certainly dates to the beginning of the period of rapid proliferation of electric installations. The 1885 Crompton dynamo at Burnfoot Lodge (Cragside) is serial number 1097 (Truman 1994), suggesting (assuming that the serial numbers used started at 1) that about a thousand machines from that manufacturer had been built, while the common use of Siemens equipment at the same time suggests that many machines of that make had entered service. How many of these early dynamos were powered by water, and how many drove early electric motors[23], it is not now possible to tell with certainty. What is more certain is that few survive on site.

The 1885 Cragside installation in Britain is more complete and in better condition than the contemporary Bullendale installation, but it illustrates the use of electric power in industrialised Britain, rather than in the remote colonies of the British Empire. Bullendale represents the movement of new technology into outlying areas, and is therefore of considerable value not only as an early power scheme, but also as a superb archaeological example of technology transfer from industrialised Britain and Europe out into the world.

12. Conclusions

The site of Bullendale and the Phoenix/Achilles Mine is a significant archaeological site for several reasons. It is a good example of a remote gold mine and associated settlement in extremely rugged country, and it contains the internationally significant remains of New Zealand's first hydroelectric industrial power scheme.

Remote gold mines and mine settlements make fascinating and valuable sites to study and visit, as they have often not been redeveloped in the way that more accessible settlements have been. The other obvious Otago example is Macetown, beside the Arrow River (Petchey 2002). Because they relied on a single economic activity with no opportunity for diversification, remote mining settlements were often abandoned as soon as the local mines failed, effectively creating archaeological time-capsules, as the dates of occupation and abandonment can often be determined accurately with little risk of subsequent contamination from new permanent occupation[24]. Bullendale is a prime example of this.

The archaeological survey identified 49 building sites at Bullendale, plus the power house site on the other side of Southberg Spur. While a number of these sites were associated with mining activities (such as two battery sites, the New Main Shaft winding house site, and the mine offices and assay office), or commercial/community activities (the Phoenix Hotel, the bakery and Bullen Hall sites), most were probably house/hut sites belonging to individual miners (and, in many cases, their families). De La Mare (1993: 34) estimated that at times of peak production there could have been up to 50 huts and houses at Bullendale,

[23] Or were used as electric motors.

[24] Many of these sites were briefly reoccupied by subsidised miners during the depression of the early 1930s.

and this is supported by the 1996 survey results. More sites than were recorded in 1996 certainly have existed, but some are now overgrown, have slipped away, or were otherwise missed during the survey.

The years of material shortages after both World War I and II led to many abandoned mining sites being scavenged for building materials (particularly corrugated iron) and for scrap. More recently, and more damaging from an archaeological perspective, the growth in interest in collecting antique bottles has led to many sites being fossicked by bottle diggers. Although now illegal on pre-1900 sites under the provisions of the Historic Places Act (1993), this activity continues. While remoteness is no protection from this latter activity (Bullendale has been subject to some very damaging fossicking), distance and lack of vehicle access can deter the removal of heavy equipment and it is for this reason that Bullendale has retained the historically important generating equipment.

It is this electrical equipment that is probably of most historic value. As the discussion above in section 11.3 has described, Bullendale is amongst the earliest surviving hydroelectric sites in the world, and is certainly New Zealand's earliest surviving electric power site. The installation of the equipment in 1885–86 generated a great deal of interest because of its pioneering nature in this country, an achievement that is made even more impressive by the rugged and remote nature of Bullendale. The slightly earlier power installations at Cragside and Godalming in Britain were in areas well serviced by roads and railways. Bullendale had only a pack track though the mountains, on the other side of the world from the industrial and commercial centres where the electric power equipment was manufactured.

Bullendale therefore is a site of international importance. It represents the rapid movement of new technology out of the Old World and into the developing New World, and the willingness of engineers and miners to adopt and adapt this technology to meet the needs of a new environment. The survival of key elements of the electrical equipment on site considerably enhances the significance of Bullendale, as it allows the visitor or researcher to examine what was cutting-edge technology, used as far away as it was possible to get from its design and manufacturing origin.

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Neville Ritchie carried out archaeological recording in the area in the 1980s, and excavated the dynamo site in 1985, and provided reports and other information about his work there. Historic mining enthusiast Peter Mason knows the area well, and shared this knowledge. John Sarginson provided information about his father's time on the Mount Aurum Station, and the construction of the farm track into Bullendale. David Clarke of the Lakes District Museum helped with historic photographs, as did the staff of the Hocken Library, Dunedin, while the staff at the Department of Survey and Land Information (now Land Information New Zealand) in Dunedin assisted with the location of contemporary maps. Ron King, the last Mines Inspector at the Mines Department in Dunedin before its closure, provided access to the mining files on the area, and allowed me to copy the plan of the underground mines at Bullendale (this plan is now held by Archives New Zealand).

My father, David Petchey (a retired power station engineer), provided engineering advice; Ralph Allen of Dunedin provided botanical advice on the plant species in the area, and Arthur William of Invercargill provided advice on the power and telephone lines and equipment used at Bullendale. Alexy Simmons provided information on other early New Zealand electrical sites. Barry MacDonnell allowed me to use some of his geological descriptions of the mine.

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The Hocken Library, the Lakes District Museum and Archives New Zealand (Dunedin Regional Office) have all given permission to reproduce material in this report.

14. References

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12/46/1187
12/46/1265

Appendix 1

SUMMARY OF CHANGES TO THE PHOENIX (ACHILLES) BATTERY

1864 (AJHR 1866 D14: 4; New Zealand Mines Record No. 11: 465)
Stampers: Four stamps, with wooden shanks shod with plate iron, wooden cam shaft, cams were wooden pegs driven into auger holes in shaft.
Power: Water wheel.

1867 (AJHR 1875 H3: 53; Otago Gazette 1867: 228)
Stampers: Thirty stamps (new plant from Melbourne). Stampers fed by automatic hoppers.
Power: Water turbine. Initially a Scheile's turbine, but this was unsuccessful. Replaced by a Whitelaw's turbine.

1869 (AJHR 1875 H3: 53)
Gold saving: Cornish pattern reverberatory furnace used to roast battery sands to remove pyrites from blanket sands, but the fumes made it impossible for men to work in battery house, so not used after 1869. (No record of when built.)

1874 (AJHR 1874 H9: 30)
Stampers: Thirty stamps.
Power: 25 h.p. water turbine.

1875 (AJHR 1875 H3: 53)
Stampers: Thirty 6-cwt stamps, with a 6- to 8-inch drop. Arranged in six batteries of five stamps. Gratings punched with 122 holes per square inch. Ore supplied by self-feeding hoppers.
Power: Water turbine in centre of battery.
Gold saving: Three quicksilver (mercury) troughs with 8 inch drop, then over blanket strakes. These varied between battery units; 14, 16 and 18 feet in length. 1–1.5 inch fall per foot. Blanket sand was rich in pyrites, so was passed through a large revolving barrel with a broad shaking table and ripple ties attached. Then it was saved with intention of grinding with quicksilver. It was intended to erect several Borlase's buddles in front of the mill. Cornish reverberatory furnace still intact, but not used since 1869.

1878 (AJHR 1878 H4:20)
Stampers: Twenty-five stamps.

1885 (AJHR 1885 C2: 11)
Stampers: Twenty stamps.
Power: Overshot water wheel[25].

1886 (AJHR 1886 C4:19)
Stampers: Twenty 7-cwt. stamps, with an 8-inch drop, 80 drops per minute. Another ten stamps being added in expectation of extra power from electric supply. Stone-breaking machine being erected to pulverise

[25] This is not confirmed by any other source.

quartz before deposition in the paddock[26]. Stampers fed by self-feeding hoppers from the paddock.

Power: Leffel water turbine, 16 inches in diameter, working under a 51-ft head of water. Steam engine during winter. Brush Victorian motor being installed.

Gold saving: Blankets below stampers. Experiments being carried out with hydraulic troughs and chemical process converting gold to a trichloride.

1888 (AJHR 1888 C5: 42)

Stampers: Ten 800-lb, twenty 650-lb stamps with a 7-inch drop, 76 drops per minute.

Power: Electric.

1889 (AJHR 1889 C2: 57)

Stampers: Ten heads being removed to test reefs in Butcher's Gully.

Power: Electric.

1892 (AJHR 1892 C3: 59; 1892 C3A: 41)

Stampers: Twenty-five heads of stamps. Machinery overhauled and timber-work renewed.

Power: Electric.

1893 (AJHR 1893 C3: 87, 211)

Stampers: Ten 750-lb, twenty 600-lb stamps, with a 7.5- to 8-inch drop, 80 drops per minute.

Power: Electric.

Gold saving: Blankets (green baize) below stampers. Blankets 18 ft long, 6ft wide. Divided into four partitions. Gradient $^7/_8$ inch per foot. Blanket sands treated in an amalgamating barrel. After amalgamation, sands passed over a Rettinger-type shaking table 8 ft × 2 ft.

1898 (AHJR 1898 C3: 102)

Stampers: Thirty 7-cwt stamps.

Power: Pelton wheel, 5 ft diameter, supplied by a race from further up Right Branch Skippers Creek. Electric power used to drive two air compressors and as an auxiliary for the battery.

Gold savings: Tables covered with green baize, three strakes each 16 ft long. Baize is washed and concentrates are treated in amalgamating barrel of 1 ton capacity for 16 hours with 100 lb of mercury. Concentrates are then stacked for further treatment.

1905 (AJHR 1905 C3: 56; 1906 C3: 115)
(Mt. Aurum Gold Mining Company)

Stampers: Ten heads of stamps put back into repair in old battery.

Ore supply: Aerial cableway under construction from British-American Spur.

Power: Pelton wheel. New water supply laid on giving 500 ft head.

Gold saving: Copper plates.

[26] This is probably the Kincaid & McQueen jaw crusher still on site.

Appendix 2

1903 MACHINERY INVENTORY, ACHILLES GOLD MINES LIMITED

Held by Hocken Archives, ms 1270, 3-3-8.

INVENTORY OF MACHINERY & PLANT, MATERIALS,
STORES, &c. on hand on the January,190[illegible]

(2)

2	6 ft. Pelton Wheels	120: 0: 0
2	1 ft. 3 in. do. do.	20: 0: 0
1	5 ft. do. do.	50: 0: 0
1	4 ft. do. do.	60: 0: 0
2	Electric Dynamos, (Power), with gearing & copper line	800: 0: 0
1	Electric Dynamo, (10 Lamp)	9: 0: 0
1	25-Light do. (old)	10: 0: 0
1	Spare Armature	100: 0: 0
1	Electric Motor (old)	60: 0: 0
2	New Electric Motors, complete	664: 0: 0
	Winding & Pumping Gear	600: 0: 0
1	Cornish Pump, complete	500: 0: 0
1	5 H.P. Tangye Winding Engine	50: 0: 0
1	10 H.P. do. do.	80: 0: 0
1	6 in. Tangye Pump with piping	50: 0: 0
2	4 in. do.	70: 0: 0
1	20 H.P. Tangye Engine	80: 0: 0
1	Steam Boiler	100: 0: 0
2	Air Compressors	350: 0: 0
2	Air Receivers	120: 0: 0
1	30 Head Battery (say)	200: 0: 0
1	Amalgamating Barrel	5: 0: 0
1	Shaking Table	10: 0: 0
1	Lathe, 5 in. centres,	40: 0: 0
1	Hand Screwing Machine	18: 0: 0
3	Hand Drilling Machines (one worn)	15: 0: 0
1	Grindstone (new)	2:10: 0
1	Stone Crusher	80: 0: 0
1	Hand Rolling Mill	5: 0: 0
1	do. Punching Machine	5: 0: 0
1	Hand Shearing Machine	2:10: 0
1	do. Quartz Crusher	20: 0: 0
1	Forge	10: 0: 0
1	Bellows	5: 0: 0
1	Anvil	3:10: 0
	Tools & Appliances	25: 0: 0
1	Bellows, (old Blacksmith's shop)	3: 0: 0
1	Anvil	1: 0: 0
1	Carpenters' Bench & Appliances	25: 0: 0
	Sundry Buckets at Battery	3: 0: 0
3	Wheelbarrows (one sold to Davis for 15/-)	2: 0: 0
1	Tangye's Crab-Winch (double purchase)	8: 0: 0
1	"Little Giant" Turbine	3: 0: 0
1	Saw-Bench with gear	10: 0: 0
2	Safes	35: 0: 0
1	Bullion Balance	25: 0: 0
1	No. 9 Oertling's Balance, with weights	24: 0: 0
3	Salter's Spring Balances	1:10: 0
1	Dial	23:10: 0
1	Rifle	4: 0: 0
1	"Remington" Typewriter	12: 0: 0
2	Black Gold Dishes	4: 0
2	Spatulas	1: 6
1	Pair Crucible Tongs	1: 0: 0
2	Double-pouring Moulds	13: 0
4	Conical single Moulds	7: 0
1	Becker's Balance	2: 5: 0
1	Set ""Becker's" Weights	1:10: 0
1	Balance (4 lb.)	1:15: 0
1	Set "Becker's" Weights	15: 0

Continued on next page

(4)

	Cupel Moulds	6: 0
10	Annealing cups	2: 6
2	Wash-Bottles	5: 0
	Test-Tubes	2: 6
1	Blow-pipe	3: 0
1	Spirit-Lamp	1: 0
1	Bead Hammer & Anvil	3: 6
1	Grinding Plate	1:10: 0
	Mathematical Instruments, Scales &c.	3: 0: 0
1	Glazier's Diamond	18: 0
1	Pack-saddle, Cart Bridle, &c.	4:10: 0
2	Bridles & Breastplates	2:10: 0
1	Riding Saddle	4: 0: 0
	Belting "Dick's"	51: 0: 0
	Small Piping	40: 0: 0
2	Matching Pieces (Pump gear)	6: 0: 0
1	Berdan Pan, complete	30: 0: 0
1	Tangye Worm-Screw & Marker	15: 6
1	Block & Tackle	1: 7: 6
4	Clybourne Spanners	2: 0: 0
5	Stocks with Dies & Taps	12: 0: 0
	Sundry Wheels, ironwork and parts of machinery &c.	20: 0: 0
7	Pieces of shafting	21: 0: 0
6	Belt Pullies	22:10: 0
3	Rope Pullies	3: 0: 0
3	Oil Casks, empty	1: 2: 6
8	Augers	1: 4: 0
3	Gold Moulds	1: 0: 0
4	Sieves	12: 0
2	Retorts	4: 0: 0
1	Silver Dish	1: 0: 0

3	Adzes	15: 0
2	Planes	8: 0
1	Bottle Jack	1: 1: 6
1	2-Ton do.	15: 0
$\frac{1}{2}$	Cwt. assorted Drifts & steel Tools	2:10: 0
3	Wood Clamps	1:10: 0
4	Hand Saws, old	8: 0
	~~kiftingxTackles~~	
3	Sets Lifting Tackle $\frac{1}{2}$ Ton	2: 0: 0
3	Sets Pulley Block & Tackle	1:10: 0
2	Battery Hammers	8: 0
1	Doz. assorted Spanners	1: 0: 0
1	Pestle & Mortar	5: 0
1	Dynamo Commutator	$5\frac{7}{8}$ 0: 0
2	Rotary "Willcox" Pumps, $1\frac{1}{2}$", & $2\frac{1}{2}$" respectively	9: 0: 0
	Sundry Pipes, Tees, Elbows, Flanges, Couplings, &c.	4: 0: 0
2	Sets Truck Pedestals	1: 0: 0
6	8" Truck Wheels - iron	4: 0: 0
6	do. do. steel	11: 0: 0
4	5 ft. Pelton Wheel Buckets	1:13: 0
2	Air Valves	2: 0: 0
1	11" Water Valve (at Creek)	10: 0: 0
1	Nozzle Ball Joint	5: 0: 0
1	22" Flange	4: 6
12	9" do.	1: 7: 0
4	5" do.	8: 0
1	7" Expension Joint	3:10: 0
1	Pelton Wheel Pinion	1: 0: 0
4	Sundry Plummer Blocks	2: 0: 0
150	Feet 5" Flange Piping (old)	5: 0: 0
26	Dies	12:15: 0

Continued on next page

15	Stamper Shoes	21: 0: 0
8	Tappets	15:12: 0
1	Cam	3:10: 0
4	Stamper Box Doors	3: 0: 0
1	Pair Shafts (for sleigh)	2:10: 0
	Furniture (House & Office)	150: 0: 0
1	House	150: 0: 0
1	do.	100: 0: 0
1	do.	40: 0: 0
1	do.	15: 0: 0
	Stores & Assay Buildings	175: 0: 0
1	Engine-House	4 00:0: 0
	Battery Building & Blacksmiths Shop	200: 0: 0
1	Stable	120: 0: 0
	Race Fluming	4000: 0: 0
	Rails,iron (in use 25 tons loose 5 tons) @ £14 2 tons sold to Sandhills Coy. for £10	420: 0: 0
13	Trucks	65: 0: 0
	Tools at branch	5: 0: 0
	Yds. Tracing cloth	
	Store at Skippers Point	10: 0: 0

Appendix 3

INVENTORY OF MACHINERY IN CREEK BEDS, SKIPPERS AND MURDOCHS CREEKS

Material is listed as observed by while heading upstream, starting in Skippers Creek at a point almost directly below Hut II, the standing miners' hut that is still in use. This list is not a complete inventory of artifacts in the streams. Much is probably buried and out of sight, while some material was certainly missed in the general jumble.

Compressed air reservoir. Riveted iron, semi-spherical ends. 134 inches long, 44 inches diameter.
Iron casting, right-angle bend.

Phoenix Hotel site

Iron plate, partially buried, with arched aperture in middle. Exposed portion measures 24 inches × 28 inches.
Compressed air reservoir, exactly as above, but ¾ buried.
Section of old boiler cut down into tank, 49 inches long, c. 60 inches diameter.
Several sections of angle iron, 2.5 inches × 2.5 inches and 1.5 inches × 1.5 inches.

Phoenix Battery site (Inventory as route turns into Murdochs Creek)

Section broken cast iron hub, originally c. 52 inches diameter.
Buried tank (old boiler) 59 inches diameter.
Cog wheel, 51 inches diameter. Half buried.
Half spoked pulley 58 inches diameter.
Iron casting.
Circular cast iron item, concentric troughs (cf. buddle).
Sections broken gear wheels.
Stamper shaft.
Stamp foot
Stamp cam.
Ore box with hinged end.
Iron roller.
Pipe with flared ends.
Cast iron box (mortar box?).
Iron piping.

Above Phoenix Battery site, Murdochs Creek

Buried iron cog wheel.
Whitelaw turbine rotor, 40 inches diameter.
Small outward flow turbine rotor, 21 inches diameter.
Cableway terminus wheel. Section missing (in creek).
Cast iron bottom for mortar box assembly.
Broken gear wheel.
Cable guide wheel, 25 inches diameter.
Two small tram wheels.
Iron strap.

Buried gear wheel.
Light tram wheel.
Section brake rim.
Buried angle spur gear, 19 inches diameter.
Whitelaw turbine rotar and spindle, 43 inches diameter.
Valve (screw) casting.
Shovel blade.
Stamper foot.
Three small tram wheels.
Iron rods and piping.

Below Southberg's Battery site

Back section cast iron mortar box.
Mortar box base?
Tram wheel.
Tram rail.

Above Southberg's Battery site

Short length tram rail.

Mouth of Adit Level (opened)

Section iron wheel (Brake wheel?).
Iron strap with handle.
Length iron tube. Threaded at one end, pivot on other.
Small tram whell.
Broken gear wheel, 46 inches diameter.

Mouth of Otago Level (opened)

Two pneumatic drills 'Holman Bros. Makers. Camborne, Cornwall'.
Tram rails.
Iron ore box.
Iron cage (shaft cage?).

Shaft Head

Two cable guide wheels beside shaft, 64 inches diameter.
Sections of 24-inch-diameter iron piping.
Ore bucket (as used on Brit-Am cableway).