Mining Lower Grade Ore: Changes in Mining Technology at Mount Lyell, Tasmania, 1927-1939

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Copper mining at Mount Lyell near Queenstown in Tasmania was initially established in the late nineteenth century adjacent to disseminated iron and copper sulphide mineralisation at the southern end of the Mount Reid volcanics, a belt of volcanic rocks running north to south along the west coast of Tasmania. Two mines, two smelters, two ports and two towns were established by The Mount Lyell Mining and Railway Co Ltd and the North Mount Lyell Copper Co Ltd. The two companies amalgamated in 1903 following extended negotiations between the well managed but poorly resource endowed Mount Lyell company and the mismanaged but well endowed North Lyell company.[1] Small higher-grade copper deposits were mined for the first 30 years of the twentieth century but have not been the main source of copper ore at Mount Lyell.

The initial mining at Mount Lyell was of a deposit of massive pyrite at the Mount Lyell mine, otherwise known as 'The Blow'. Initial high grade gold and silver mineralisation gave way to lower grade copper ore, a source of iron sulphide (pyrite) for fuel in the pyritic smelting process and then as pyrite feed for fertiliser manufacture. The high grade copper deposit at the North Lyell mine was the backbone and at times the sole ore source at the amalgamated Mount Lyell operation. The chalcopyrite and bornite mineralisation in the ore at the North Lyell mine, referred to in this paper as high grade ore, supported an economically robust operation with direct smelting and later a combination of concentration by gravity and froth flotation, followed by roasting and blast furnace smelting of the concentrates. The major source of copper at Mount Lyell, the disseminated pyrite and chalcopyrite ore, referred to as low grade ore, was yet to be recognised as an economic resource, due to significantly lower copper grades. The adoption of new technologies in the 1930s made their exploitation feasible and this paper attempts to highlight some of the main technological changes that were introduced by the management to enable this to occur. The different types of ore and estimated production from 1896 to 30 June 2009 are shown in Figure 1.

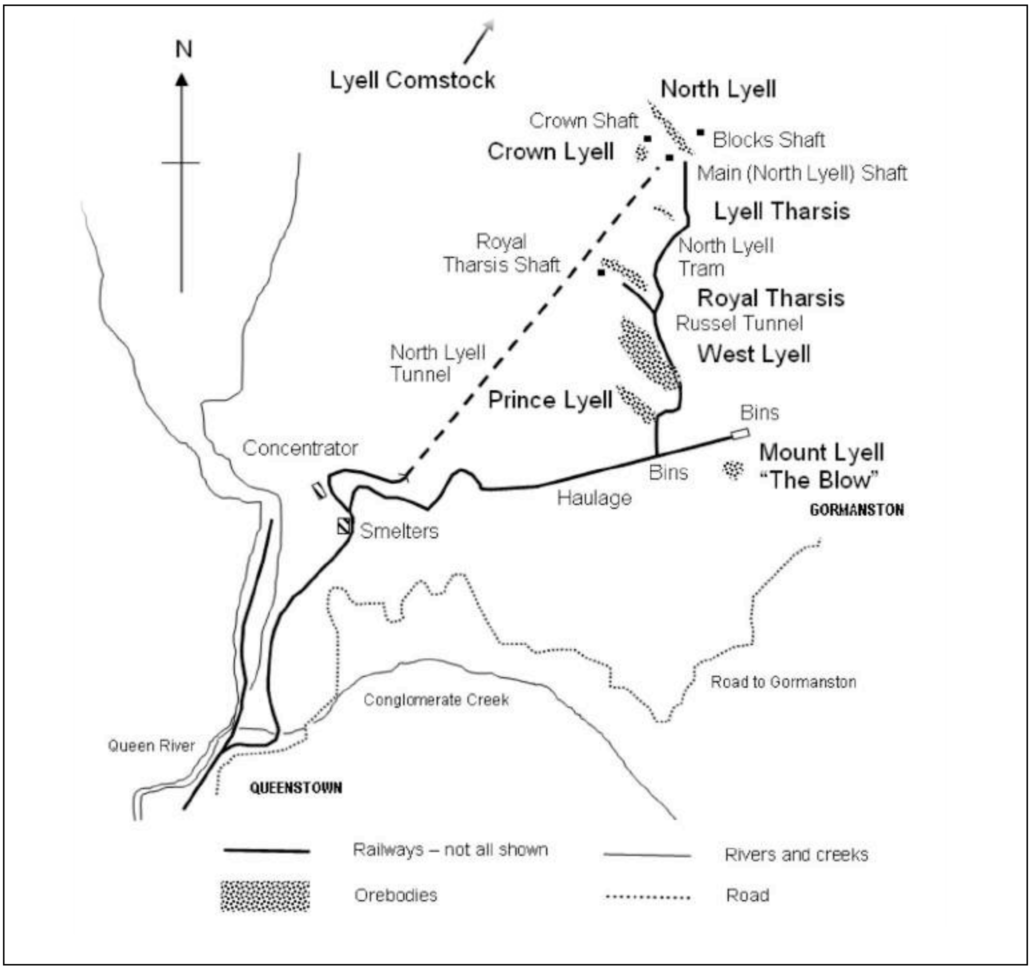
There was a major step change in the copper ore grade from an average of 4.5 percent copper in the high grade bornite-chalcopyrite ore to an average of 1.0 percent copper in the low grade disseminated pyrite-chalcopyrite ore. The locations of these deposits are shown in Table 1 and Figure 1.

Table 1: *Production from Mt Lyell to June 2009*

Orebody type	Example	Ore Production (million tonnes)	Contained Copper (per cent)	Contained Copper (tonnes)
Massive pyrite	Mount Lyell ("The Blow")	6	1.3	72,000
Bornite-chalcopyrite (high grade)	North Lyell	7	4.5	317,000
Disseminated pyrite-chalcopyrite (low grade)	West Lyell and Prince Lyell	133	1.0	1,393,000
Total		**145**	**1.2**	**1,782,000**

Source: Figures derived from P. Hills, 'Mount Lyell copper-gold-silver deposits', in F.E. Hughes (ed.), *Geology of the Mineral Deposits of Australia and Papua New Guinea,* 1990, pp. 1257-66; The Australasian Institute of Mining and Metallurgy (AusIMM), Report of the Division of Mines and Mineral Resources, 1989-1990; Department of Resources and Energy, Report for the year ended 30 June 1991; Tasmania Department of Mines, Annual Report for the year ending 30 June 1992; and Mineral Resources Tasmania Annual Reviews, 1992-93 to 2008-09.

Figure 1: *Plan of Mt Lyell operation*



Source: Based on plan in G.F. Jakins and E. Barkley, 'The North Lyell Tunnel, Tasmania', *Proceedings Australasian Institute of Mining and Metallurgy* (*AusIMM*), 74, 1929, pp. 41-56.

Following a visit by the general manager Russell Murray to North America in the 1920s, a tunnel was excavated from a valley near the concentrator and smelters to the base of the North Lyell mine. The completion of the tunnel in 1928 resulted in the replacement of a long and complicated haulage route and a 17 per cent reduction in the mining unit cost from 23 shillings per ton in the last full year of the old system to 19 shillings per ton in the first full year of haulage through the tunnel.[2]

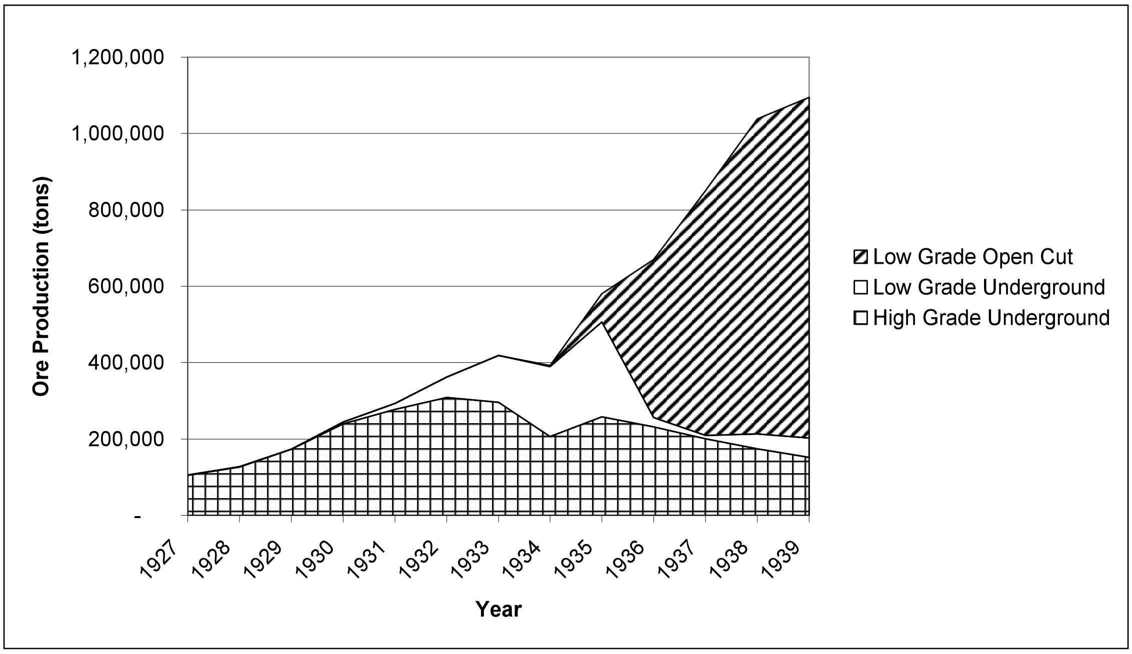
The ore reserves in the mines with higher-grade ore including the North Lyell and Lyell Comstock declined from 1928 and replacement ore sources were required. The growing recognition of the potential for the low grade resource in the 1920s led to underground mining and the use of new technology in the 1930s. The discovery of additional low grade resources in the 1930s coincided with diminishing high grade ore reserves. The relatively novel use of rubber tyred trucks in the opencut, compared to small-scale rail haulage used in previous opencuts at Mt Lyell, enabled the economic mining of larger quantities of lower grade ore and the quantity of copper produced from Mt Lyell to be increased.[3]

The ore reserves published each year in the 1930s were sufficient for an estimated ten-year mine life with the development of low grade underground resources. This continued the trend for an estimated ten-year mine life previously based on smaller high grade ore reserves and a lower ore production rate. A stacked graph of the annual ore production of ore from the different sources is shown in Figure 2 and a stacked graph of copper production from the various ore sources is shown in Figure 3. The copper production is estimated from company and government annual reports.

The copper produced came almost entirely from the high-grade sources in 1931, although there was a small amount of low grade ore from the Crown Lyell and Royal Tharsis underground mines. Production of copper from low grade underground ore increased gradually to 1933 and peaked in 1935. The dip in total production in 1934 was due to a drought during which ore production was suspended for a total of three months.[4] The majority of copper came from high grade sources, but in 1935 there was some minor production from low grade opencuts. This rapidly increased with over 60 per cent of contained copper in the ore coming from the opencuts in 1939.[5]

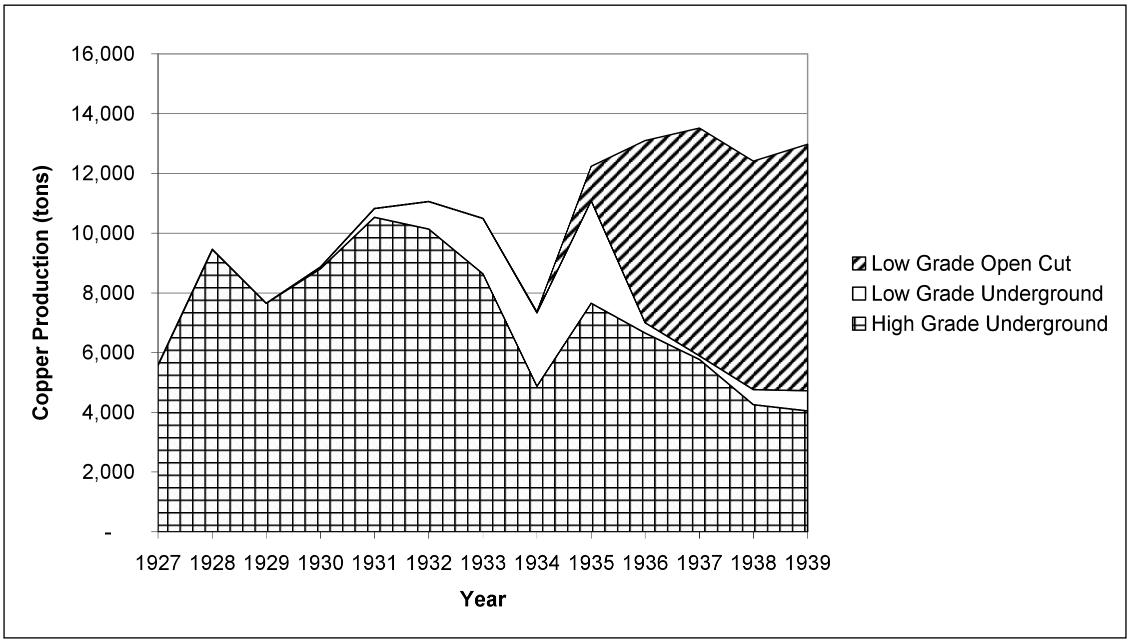
The revenue from and the cost of site production are estimated as real unit costs (in 1939 Australian pounds) for the period 1927-1939, sourced from company and government annual reports and retail price index numbers. The value of site production estimated from the total value of the copper, gold, silver and pyrite concentrate production is used as a proxy for revenue.[6] A graph of these two series is shown in Figure 4.

Figure 2: *Stacked graph of ore production sources from 1927 to 1939.*



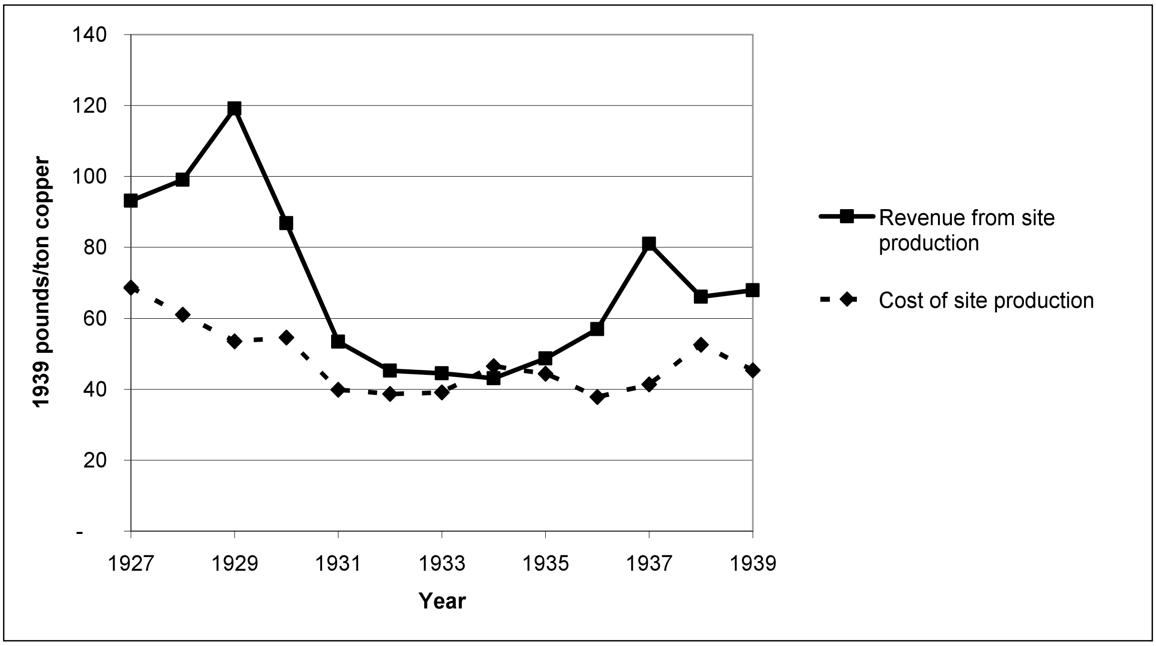
Source: The Mount Lyell Mining and Railway Co Ltd, Reports and Statements of Accounts for the years ended 30 September, 1927 to 1939, and Report of the Secretary for Mines, Tasmania, for year ending 31 December 1927 to 1939.

Figure 3: *Stacked graph of copper production sources from 1927-1939.*



Source: The Mount Lyell Mining and Railway Co Ltd, Reports and Statements of Accounts for the years ended 30 September 1927 to 1939, and Report of the Secretary for Mines, Tasmania, for year ending 31 December 1927 to 1939.

Figure 4: *Revenue and cost of site production 1927-1939*



Source: The Mount Lyell Mining and Railway Co Ltd, Reports and Statements of Accounts for the years ended 30 September 1927 to 1939, and Report of the Secretary for Mines, Tasmania, for year ending 31 December 1927 to 1939.

The unit revenue of site production declined from 1929 with the steep drop in the copper price following the arrival of the Great Depression. The mine site is estimated to have made a cash loss in 1934 and this was partly due to the drought. The unit cost for the site decreased to 1931 and then gradually increased in line with the higher proportion of low grade opencut ore being produced.

Unit costs for different production sources are estimated using multiple linear regression. The estimated average total cost of copper production from high grade underground and low grade opencut sources were similar at about £A45 per ton of refined copper. The average cost of low grade underground sources was about £A60 per ton of copper which was above the value of site production for a considerable period during the 1930s. Despite the application of new technology to low grade underground resources this change was not sufficient to make these economically viable, as mentioned in the following sections. By contrast the new technology adopted for low grade opencut mining enabled production of copper at about the same cost as the existing high grade underground operation. Significant changes to the concentrator during the 1930s also contributed to the successful economic opencut mining of low-grade ore at Mount Lyell.[7]

North Lyell Tunnel

In 1927 the transport of ore from the stopes underground to the concentrator included eight stages. Blainey describes the inefficiencies of the process thus:

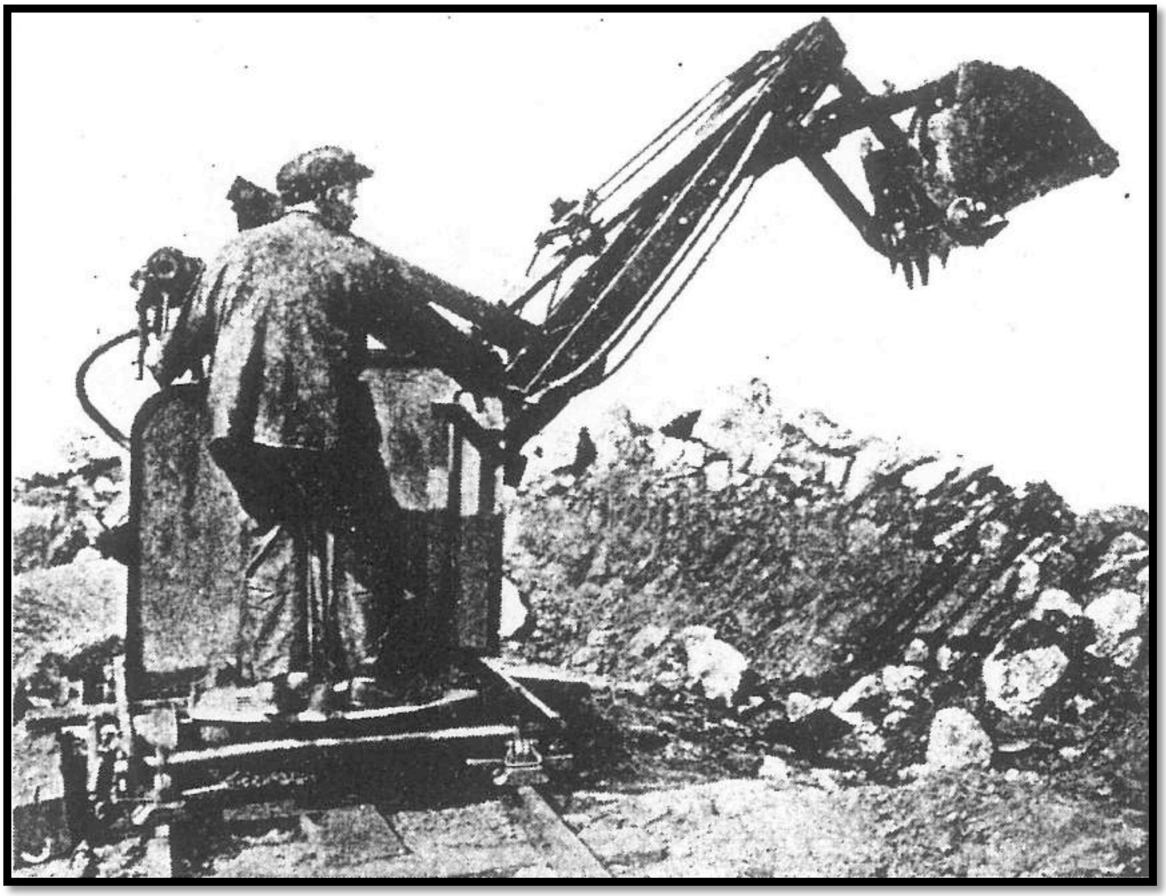
> A miner drilled and blasted the ore on to the ground of the stope; a labourer shovelled it down the ore pass to the drive; a 'trucker' filled his iron truck and pushed it along the rails to the cage; the engine driver hauled the cages to the surface; a horse hauled the rake of trucks along the tunnel to fresh air; a steam locomotive hauled the little trucks along the ridge to the ore bins at the top of the haulage tramway; larger trucks were filled with ore and lowered down the haulage by cable; and another steam locomotive carried it around the gully to the ore bins at the reduction works.[8]

Tunnels for transporting ore from the mines to the treatment works at Queenstown had been proposed since the 1890s.[9] The idea for a tunnel to the base of the North Lyell mine was revived following a visit to mines in North America by general manager Russell Murray. Murray had inspected underground mines developed on a large scale with high capacity haulage systems using overhead wire electric locomotives and other features such as mechanical shovelling.[10] The mine superintendent, Fred Jakins, justified the capital cost of the tunnel by estimating potential cost savings from a shorter and simpler haulage route, and elimination of most pumping from the mine. It is also likely that the economies of scale with a higher production rate, increased ore reserves at a lower cut-off grade in the North Lyell orebody and the opportunities of mining other known lower grade ore were also considered.

The North Lyell tunnel was excavated for a total length of 7,000 feet[11] in two headings - from an adit at the concentrator end and from the North Lyell shaft.[12] Mechanical loaders were used for loading broken rock into rail trucks at the adit end of the tunnel, one of the earliest examples of this type of technology being used in Australia. The two loaders used were the compressed air powered Butler underground shovels, made by the Nordberg Manufacturing Co.. They featured a slewing loading bucket, which contrasted with the overhead loading on the Eimco rocker shovels used widely from the 1930s.[13] A photo is shown in Figure .

The tunnel was equipped with trains of six 10-ton capacity ore trucks hauled by a single nine-ton electric locomotive. The trucks were considerably larger than the half-ton ore trucks generally used underground in Australia at the time. The system had a haulage capacity significantly above the 173,000 tons produced from the North Lyell mine in 1929 after commissioning in 1928. The same type of equipment, with some additions, was capable of hauling over two million tons per year of crushed ore during the 1960s through the West Lyell tunnel, though over a shorter distance. [14]

Figure 5: *Butler Underground Shovel*



Source: Mechanical loading in tunnels and mines, *Chemical Engineering and Mining Review*, September 5, 1927, p. 453.

One of the results from development of the tunnel was the centralisation of the mining department in Queenstown on the western side of the ridge that separates Queenstown and Gormanston. Personnel were transported underground from the changerooms and mine offices on the Queenstown side in dedicated passenger cars. The mining department had previously been based on the eastern or Gormanston side of the ridge.

Rising of the Royal Tharsis Shaft

A shaft was raised, or developed upwards from the 1,100ft level underground to the surface at the Royal Tharsis orebody, a distance of 866ft, [264metres] which was at the time an unusual method for developing a major shaft. Shafts were generally developed as blind sinks down from the surface with drilling and blasting at the base and hand loading of the broken rock into kibbles for hoisting to the surface. One of the reasons for shafts generally being developed as blind sinks was the lack of additional capacity for men, materials and rock handling underground. The rising method used at Royal Tharsis allowed quicker advance and a lower unit cost than a blind shaft sunk from surface.[15] After completion of the shaft excavation a small winder was erected on the surface and horizontal ropes from the winder ran over the sheave wheels and down the shaft.

Tailings Backfill

The backfill systems for the North Lyell and Crown Lyell underground mines provided a level or moderately inclined working surface in the stopes and stabilised the excavations. Backfilling also avoided the hazard of fire associated with timber support in stopes without backfill. Weathered rock and associated clay were excavated in two opencuts using steam shovels powered by compressed air, and later, a small electric shovel, while small trains carried the rock and clay to passes from the surface to stopes underground. Water was added to the rock to improve both the flow of the rock and improve consolidation of the fill.[16]

A new system using concentrator tailings mixed with water, known as hydraulic fill, was selected for backfilling the Royal Tharsis mine, because a suitable rock backfill material was not available on the surface above the Royal Tharsis orebody. Pumping of the hydraulic fill over long distances was found to be technically and economically feasible and tests of the quick setting properties of the tailings were encouraging. The finer portion of the tailings was removed at the concentrator and the coarser portion pumped along the North Lyell tunnel in stages, with a centrifugal pump at each stage, and then through the Royal Tharsis shaft up into the stopes. The water drained from the tailings and resulted in a flat working surface. This was one of the earliest examples of hydraulic fill being used in Australia. It was also unusual in that the hydraulic fill was pumped up into the mine. At most mines in Australia the concentrator is located at a higher level and the hydraulic fill fed from the surface by gravity.[17]

Shafts

Hoisting in the main (North Lyell) shaft was performed by an electric winder from the 1,110 feet deep shaft, hoisting trucks of ore in two balanced cages. The electric winder had an equalised Ward Leonard (motor-generator) control using a flywheel (also known as the Ilgner system) driving a 400hp direct current winder motor.[18] This winder was commissioned in 1908 and was one of the early electric winders in Australia using the equalised Ward Leonard system.[19] The site power supply at this time was from a small steam power station at the smelter, which probably had insufficient capacity to supply the high peak power loading required when a mine winder accelerates.

Other electric winders were installed for men and materials hoisting after this time and by the mid 1930's all the surface winders were alternating current winders with liquid resistors for starting and accelerating the winder motor.[20] A liquid resistor is a low technology device compared to the equalised Ward Leonard control system formerly used for the main shaft, but it was suitable for these particular applications. By this time there was also a large hydroelectric power station at Lake Margaret capable of absorbing any variations in power demand from the winders and other electrical equipment at the site. These smaller winders demonstrate the use of appropriate low technology compared to, in this case, unnecessary high technology.

Underground Mining

The cut and fill stoping method used at the Royal Tharsis mine was developed from the method used for a considerable period at the North Lyell mine. The ore is likely to have been moved within the stopes by hand shovelling, rather than by compressed air or electric powered scrapers, which would have reduced costs. The improved labour productivity and reduced costs using scrapers would probably have been insufficient to make for economic underground mining, which would have likely required the use of a bulk mining method such as the large open stopes used at Wiluna or Mount Isa in the 1930s.[21] Both Russell Murray and Fred Jakins were civil engineers by training and long term employees at Mount Lyell: Murray as mine manager (1906-21) and general manager (1922-44) and Jakins as mine superintendent (1921-48). Murray had since 1912 also depended on a long term underground foreman or underground manager, John Pearton, who retired in 1944, the same year as Murray.[22] This combination of non-mining training and length of experience at a single site probably militated against changes in the fundamentals such as the stoping method. Despite some innovations in underground mining at Mount Lyell, the higher cost of copper sourced from low grade underground ore defeated the technology.

Opencut Mining

During 1934 the old workings of the Russell Tunnel were reached by a drive 1,200 ft long from the south end of the highest level at the Royal Tharsis orebody. The main objective was to investigate low grade mineralisation found in the 1890s, a resource proved further by diamond drilling and longhole percussion drilling. The reserve calculated in 1934 for these West Lyell orebodies was one million tons at 2.25 per cent copper, only 0.2 percentage points less than the total ore reserve at this time and equal to the head grade for the ore treated in 1934.[23] The West Lyell orebodies were close to surface and amenable to opencut mining. Prior to this time opencut mining of ore at orebodies such as the original Mount Lyell mine had been performed on narrow benches by hand drilling and blasting and loading by hand shovels into small rail wagons.[24]

Small scale underground mining in the West Lyell orebodies commenced early in 1935 and continued for a relatively short time until May 1935 when opencutting commenced. On the West Lyell No 1 orebody a one cubic yard electric shovel loaded into 3½ ton capacity rubber tyred trucks, which hauled the ore to the Royal Tharsis main transfer pass. The Ford trucks were hired from Perpetual Trustees in Hobart and came with an unusual arrangement of rollers on the side of the tray which engaged with a ramp at the ore pass to tip the tray.[25] Some hand loading with shovels was also performed into 3½ ton capacity trailers drawn by tractors.

The method of opencutting the West Lyell No 2 orebody was a little different, and owed more to underground mining. The broken ore which was scraped using scraper hoists and hoes to passes down to the Royal Tharsis No 1 level underground was then loaded into rail trucks and hauled by horse to the Royal Tharsis orepass. In both cases the ore was finally hauled along the North Lyell tunnel to the concentrator.[26] Larger shovels of two and half cubic yard bucket capacity and trucks up to 12 tons capacity were subsequently introduced. Mechanisation reduced the amount of manual labour required but introduced new hazards as illustrated by an accident report recorded by the mines inspector in the opencut at Mount Lyell:

> A stone dislodged by scraper chain from the face 22 ft high in an open cut struck an employee on the head, causing injuries from which he died four hours later. Evidence at the inquest disclosed that there was no reason for the deceased to be at the part of the face where he was injured. A finding of accidental death was recorded.[27]

An interesting development during this period was the purchase of three International petrol trucks, two of which were of the conventional three-axle configuration and the third a two-axle semi trailer prime mover with a single axle trailer.[28] Larger capacity trucks purchased after the Ford trucks were introduced, had hydraulic hoists to tip the load of rock from the tray. A high level bridge was constructed for these larger trucks to tip material into the Royal Tharsis orepass.

An opencut mine of this size in the 1920s would most likely have used rail equipment to transport ore and waste from the face to a crusher or waste dump, a good example in Australia being the mine at Iron Knob, near Whyalla in South Australia, which installed heavy electric locomotives and trucks in 1928.[29] Mount Lyell was among other such opencut mines in Australia, for example, Mount Morgan, which introduced rubber tyred truck transport during the 1930s. There was a similar trend to rubber tyred transport in the iron ore mines near Lake Superior in the United States in the mid to late 1930s.[30]

Despite the mechanisation of loading and hauling, the drilling and blasting of the 50 foot high benches in 1940 relied on hand held 55 pound jackhammer drills. These were used to drill three sets of 18-foot long vertical holes, and a series of lifter (flat) holes to give a flat floor for charging with 1¼ inch diameter cartridges of gelignite explosive. Bulling also took place at the toe or bottom of the holes. Bulling was an operation in which one or more charges were initiated to enlarge the diameter at the bottom of the hole (toe) to allow a larger subsequent charge of explosive at the toe, where there was generally a larger burden or amount of rock to be moved in blasting.[31] It is not known whether the three sets of 18 ft holes were fired simultaneously or sequentially. This type of drilling was in common use at other opencut mines in Australia until the advent of larger diameter churn drills for opencut drilling in the late 1940s and early 1950s. Many rocks from the primary blasting at Mount Lyell also required additional breaking by hand or drill and blast.

The Mount Lyell operation exceeded one million tons of ore production in 1938, including 825,000 tons from the West Lyell opencut, and was one of the larger mines in Australia at this time.

Conclusions

Opencut mining of a low grade resource using electric shovels and rubber tyred trucks had been proven as a technical and financial success and the remaining underground mining rapidly declined during the Second World War. Changes in the mining technology were primarily responsible for development of the large low grade copper resource at Mount Lyell, initially as uneconomic underground operations and later as a large opencut mine.

Endnotes

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