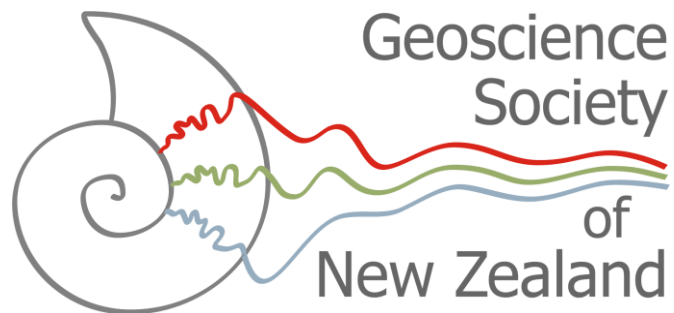


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# Processing gold-bearing quartz ore in the early twentieth century: an illustrated case history from the Snowy River battery, Waiuta, New Zealand

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## Abstract

The Snowy River battery near Waiuta, New Zealand, processed gold-bearing quartz ore from the nearby Blackwater mine between 1908 and 1938. Incorporating the latest technology when built in 1908, it was a typical, early 20th century processing plant. This case study of how gold was extracted from the ore is illustrated by a sequence of photographs taken by Joseph Divis in early 1931.

Roasting of the ore concentrates after 1924 had the unanticipated consequence of contaminating part of the area around the battery with arsenic, which persists in the soil today. In 2015 plans are underway to remediate the most badly contaminated site.

**Keywords:** quartz reef, gold, ore-processing, cyanide, mercury, arsenic, Blackwater mine, Joseph Divis

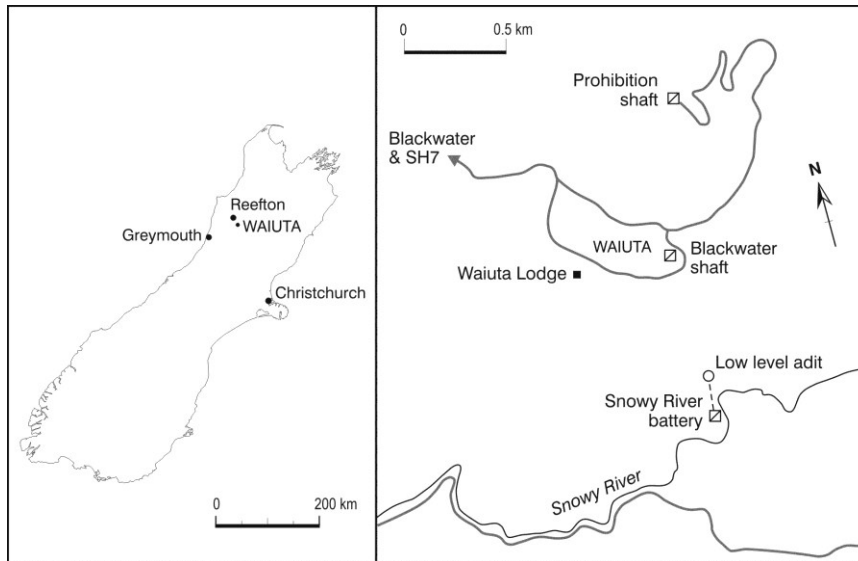
## Introduction

Gold-bearing quartz reefs have been the source of much of the gold recovered throughout the world from Roman times until the present day. By about 1900 the processing of quartz ore had become standardised, consisting of several steps:

1. Crushing to release the gold (and any other minerals);
2. Capture of free gold on mercury-coated copper plates or by amalgamation with mercury;
3. Physical concentration of gold and other heavy minerals not captured in step 2;
4. Cyanide treatment to dissolve gold, then re-precipitation by reaction with zinc;
5. Smelting of gold bullion

Although there are many general descriptions of ore processing in the early twentieth century, there is little detailed information available for mining operations in the South Island of New Zealand. The Snowy River battery, processing ore from the nearby Blackwater mine (Fig. 1) has recently been studied as a heritage project, and provides an illustrated case history of technology that has long been superseded. The equipment and sequence of operations at the Snowy River battery have been documented by Wright (2007), based on historic records and interviews with those associated with the battery. This is supplemented by a sequence of images taken in early 1931 by photographer Joseph Divis for a feature in the *Auckland Weekly News* (Nathan 2010, 2011). Only a few of the images were published, but the whole set of more than 30 photographs provides a unique record of the way that gold-quartz ore was processed in the Snowy River plant.

The Snowy River plant was regarded as state-of-the art technology when it was constructed in 1908. Some modifications were made over the years, especially the addition of an Edwards roasting furnace in 1924 and continued modification of the cyanide process, but by 1931, when the photographs were taken, the plant was regarded as primitive and old fashioned. A new plant, incorporating new technology, was built near the Prohibition shaft and opened in 1938, and the Snowy River plant was abandoned.



**Figure 1.** Location map of Waiuta, showing the relative positions of the Blackwater and Prohibition shafts as well as the Snowy River battery.

### Photography by Joseph Divis

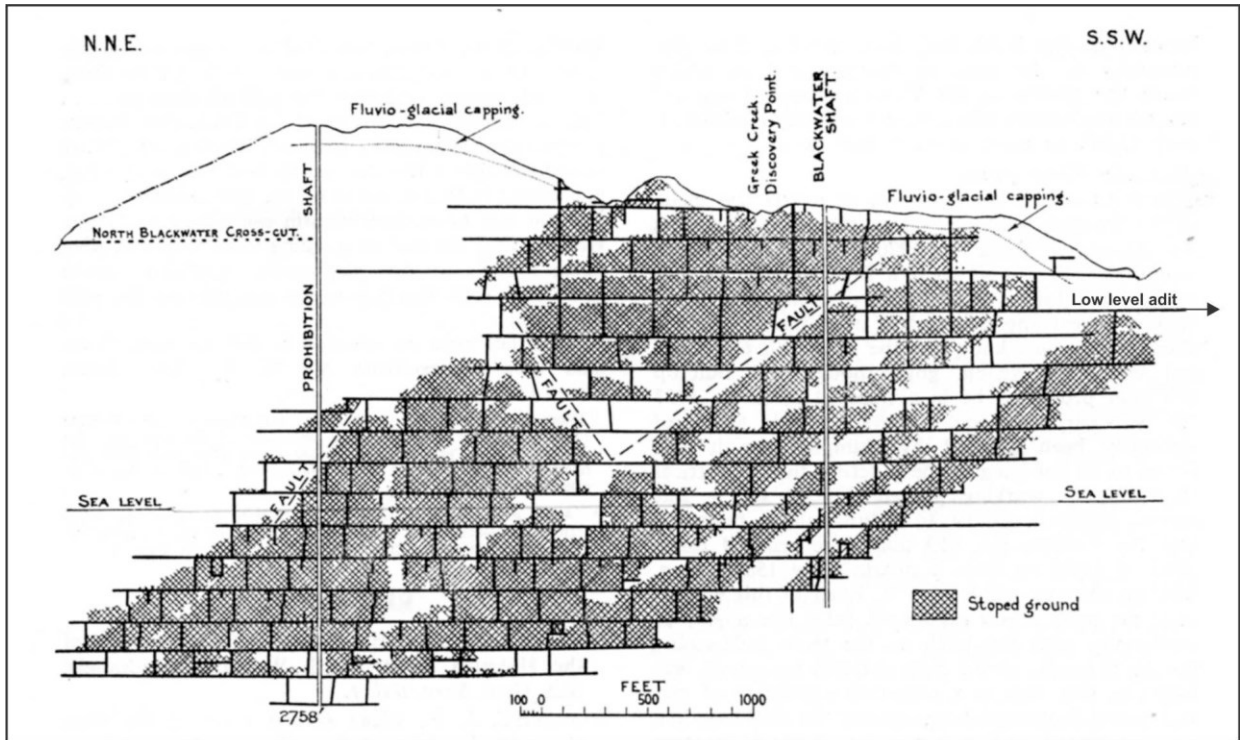
Joseph Divis was a working miner in the Blackwater Mine, but in his spare time he was also a skilled photographer. Most of the photographs of the Snowy River battery were taken when the plant was idle, probably during the 1930-31 Christmas break. The same people occur in many of the photographs: Jack McEwin (battery manager) and his sons Andrew and Ian; Frankie Orr (assistant battery manager); and Ted Allen (assayer); Divis normally used a time release to control the camera shutter, and he often appears in his photographs dressed in a distinctive outfit that locals called his 'safari suit'.

Unless stated otherwise, the photographs in this paper were taken by Divis. The original glass plate negatives are now held in the Alexander Turnbull Library, Wellington, and the Hocken Collections of the University of Otago Library, Dunedin. The negatives of a few images could not be found, and these have been copied from the *Auckland Weekly News* and other sources.

### Blackwater mine

After a gold-bearing quartz reef was discovered in a tributary of the Snowy River in 1905, the London-based mining company, Consolidated Goldfields of New Zealand, acquired mining rights to the reef, and set up a subsidiary, Blackwater Mines Ltd, to work it. Sinking of the Blackwater shaft started in 1907 as well as the construction of a battery and processing plant in the Snowy River valley, 900 metres away.

The Blackwater reef proved to be a remarkably regular and persistent, steeply-dipping quartz lode, progressively mined downwards to a depth of 750 metres below the surface outcrop over 44 years (Fig 2). It averaged only 0.6 metres in width, although locally ranging from only a few centimetres up to 4 metres wide. The ore was pale bluish-grey streaky quartz, containing minor sulphides (mainly pyrite and arsenopyrite) and finely disseminated free gold (Williams 1964, pp 30-31). In 1910 the average gold content of the ore recovered from the mine was 10.7 dwt/ton (= 16.4 gm/tonne) (Henderson 1917, p 27). The gold grade in the reef was remarkably uniform over 40 years it was mined.



**Figure 2.** Vertical plan of the Blackwater mine workings after the mine closed in 1951. Until 1938 only the Blackwater shaft was used. Gold-bearing quartz was lifted up the shaft to no 3 level, then transported by trolley underground through the Low level adit, and thence by tramway to the Snowy River battery.

*Source:* Fig 3-6 in Williams (1965). *Reproduced with permission from the Australasian Institute of Mining and Metallurgy.*



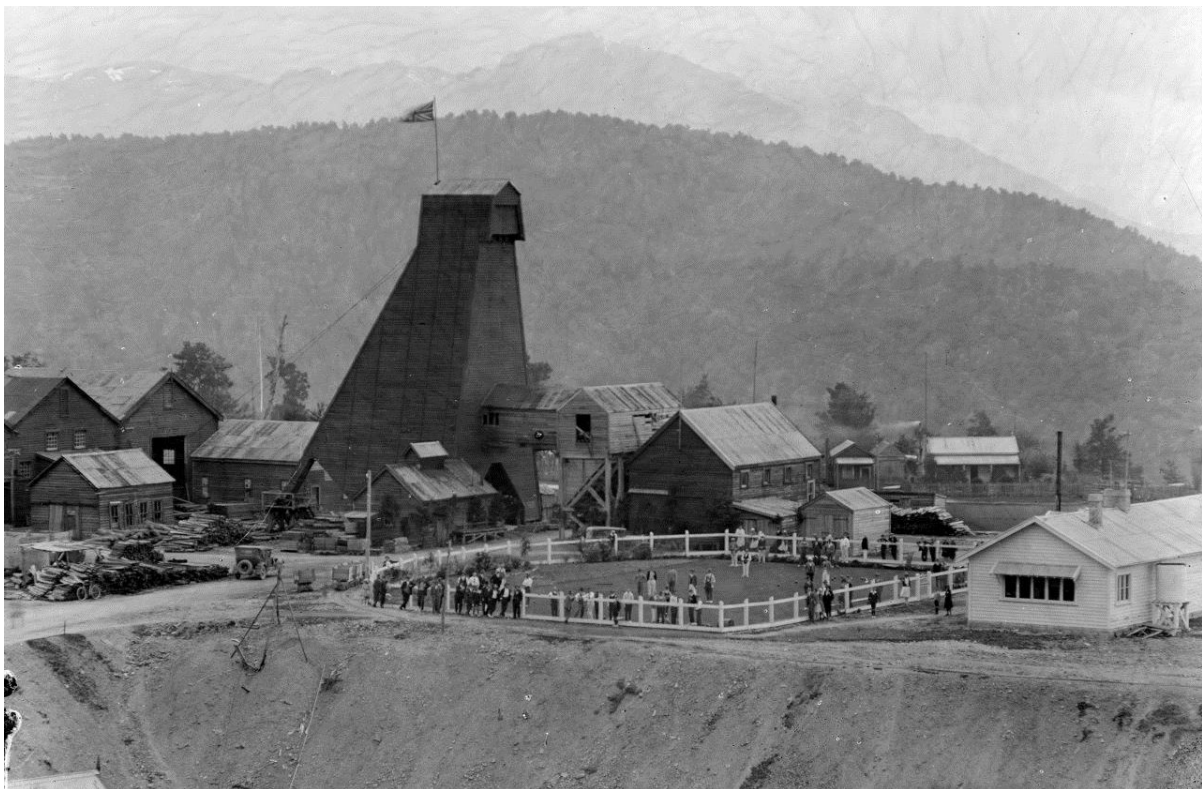
**Figure 3.** Quartz reef (white), locally up to 1.7 metres wide, at no 14 level in the Blackwater mine, with darker greywacke country rock on both sides.

*Hocken Collections, S09-323g*

The light-coloured quartz contrasted with the much darker greywacke (Greenland Group) country rock (Fig. 3). The miners tried to extract all the quartz, with as little greywacke as possible. Inevitably, however, the quartz ore taken out of the mine always contained a varying amount of barren country rock.

Transporting ore from the mine to battery was slow and labour intensive. Miners shovelled the ore and country rock extracted at the face into wagons which were pushed along rails to the main shaft, then lifted by cage to bins at a higher level and emptied into a storage bin at no 3 level. It was then transported through the mine along the Low-level adit by a horse-drawn tramway, and then around the side of the hill to the top of the battery.

While the mining company would have preferred to concentrate on extracting quartz, the miners had to spend a considerable amount of time tunnelling through barren greywacke to form tunnels and shafts, and to enlarge their working spaces. The barren rock (mullock) was hoisted up the Blackwater shaft to the surface where it was mounded up as mullock heaps, and later spread out (Fig 4).



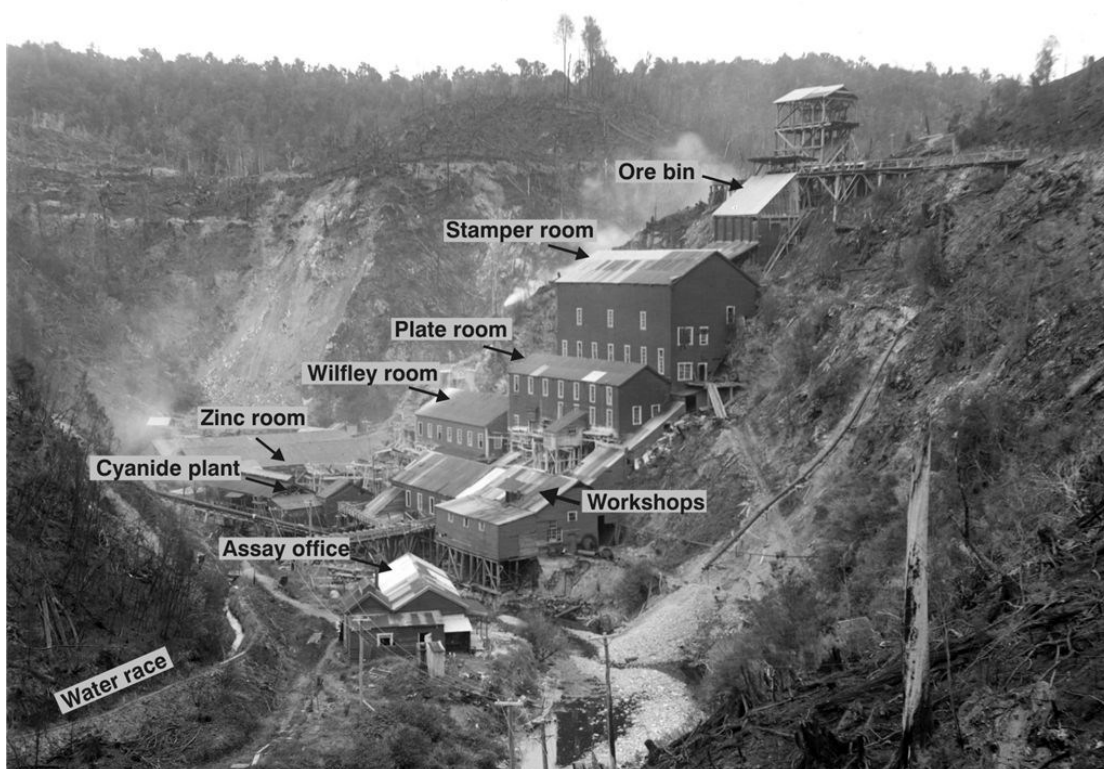
**Figure 4.** Poppet head over the Blackwater shaft, and surrounding mine buildings. The large amount of mullock (waste rock) from the mine was dumped near the shaft, and in 1931 was smoothed out to make a bowling green for the community at Waiuta.

*Alexander Turnbull Library, 1/2-233050-G*

## Snowy River battery

The Snowy River battery was sited on the side of a steep valley (Fig. 5) so that gravity could be used to move the ore as it was processed through different stages of gold extraction.

Most of the plant was powered by water. A series of belts from a Pelton wheel turned the main shaft for the stampers. There were also smaller wheels for the Wilfley tables, air compressor and small power generator. Because the water supply was inadequate in dry weather, the supply was supplemented in 1923-24 by a longer water race from streams further away



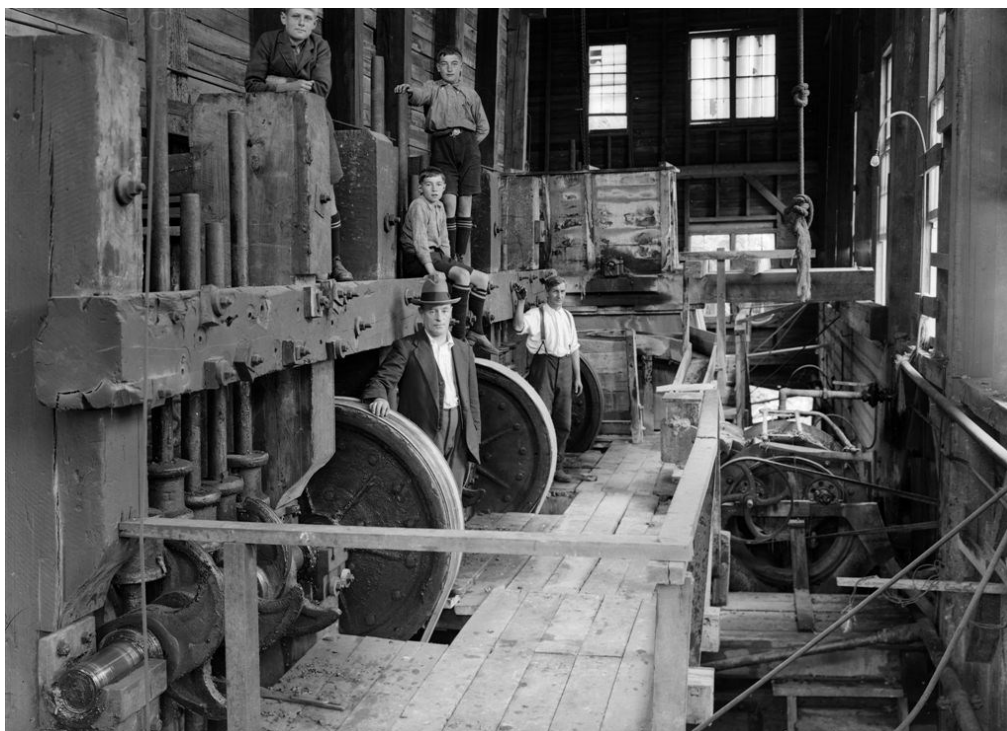
**Figure 5.** View of the Snowy River battery, with buildings labelled.  
*Alexander Turnbull Library, 1/1-39807-G*

### ***Crushing the quartz***

When quartz arrived at the battery it was dumped on the grizzly bars – a grille of heavy steel bars, 37 mm apart. Lumps too big to drop between the bars in the storage bin went to a jaw crusher that reduced them to smaller pieces.

Automatic feeders allowed stone to fall into apertures behind the mortar boxes, large iron structures resembling upright pianos, where stamper shoes at the bottom of the stamper rods pounded against replaceable dies, and crushed the quartz to a powder (Figs 6 & 7). The rods were lifted by curved finger-like cams on shafts, driven by belts from the battery's Pelton water wheel. The operation of the stampers was incredibly noisy, but in the 1930s no-one wore any hearing protection.

Water was fed into each mortar box during crushing, to produce a pulp (slurry) that passed through a mesh screen in front of the mortar box. A launder – an open timber flume – took the pulp through to the plate room for the first stage of recovery.



**Figure 6.** Sets of five stampers were operated by belt driven bull wheels. The finger-like cams (lower left) lifted and dropped the stampers to crush the quartz in mortar boxes (see Fig. 7). *Alexander Turnbull Library, ½-233103-G*



**Figure 7.** Mortar box with the front removed, showing five stamper shoes. The quartz ore mixed with water was pounded by the stampers to produce a slurry. *Alexander Turnbull Library, ½-233105-G*



When the ore supply was plentiful, two mortar boxes were fitted with larger mesh screens, and the pulp, coarser than normal, ran into a separate launder leading to an elevator that fed it onto a revolving screen. The fine pulp dropped into a launder leading directly to the plate room, while the coarser material ran down another launder to the tube mill – a revolving steel cylinder containing hard flint stones that completed the work of crushing the pulp to the required size.

### *Amalgamation*

Within the plate room, the pulp flowed to spreaders at the head of nine copper amalgamating plates (Fig 8). Each plate was 3.5 x 1.45 metres, highly polished, and laid on a slightly inclined table. The plates were smeared with a chemical agent so that mercury poured on to it formed an even film all over the copper surface.

When the pulp flowed over the treated copper plates, the fine particles of gold amalgamated with the mercury coating on the plates. The rest of the pulp flowed away in a launder for further treatment apart from the sand fraction that fell into a trap at the bottom of each table. All the plates were carefully scraped each morning, the amalgam was placed in a basin, and the plates were re-coated with mercury.



**Figure 8.** The plate room, where the slurry flowed over copper amalgamating plates coated with mercury. Fine gold amalgamated with the mercury, and was stuck to the coated plates.  
*Alexander Turnbull Library, 1/2-233106-G*

Amalgam from the plates, sand from the traps, and some additional mercury was placed in a berdan – a slowly revolving steel bowl containing a fixed iron drag that ground the material. The amalgam was further cleaned with caustic soda and a steady stream of water. Each day the berdan was cleaned out and the amalgam squeezed through calico to remove excess mercury and leave a solid ball of amalgam.

About 80% of the gold recovered at the battery was obtained from the amalgamation process. The remainder was recovered by a succession of other processes that varied over the years, but included wilfley concentrators, roasting, and cyanide treatment.

Gold values were routinely checked at all stages of the process in the assay room (Fig 9).



**Figure 9.** The gold content of the ore was checked at several stages from when it left the mine to the final smelting in the assay office, across the river from the battery. From left, the staff are Ted Allen, Frankie Orr and Jack McEwin.

*Alexander Turnbull Library, 1/2-233108-G*

### ***Wilfley concentration and roasting***

Following the amalgamation processes the remaining slurry was sorted into size fractions in a spitzkasken – a hydraulic device shaped like an inverted pyramid in which a downward current separated coarse pulp (sands) from the finer material (slimes).

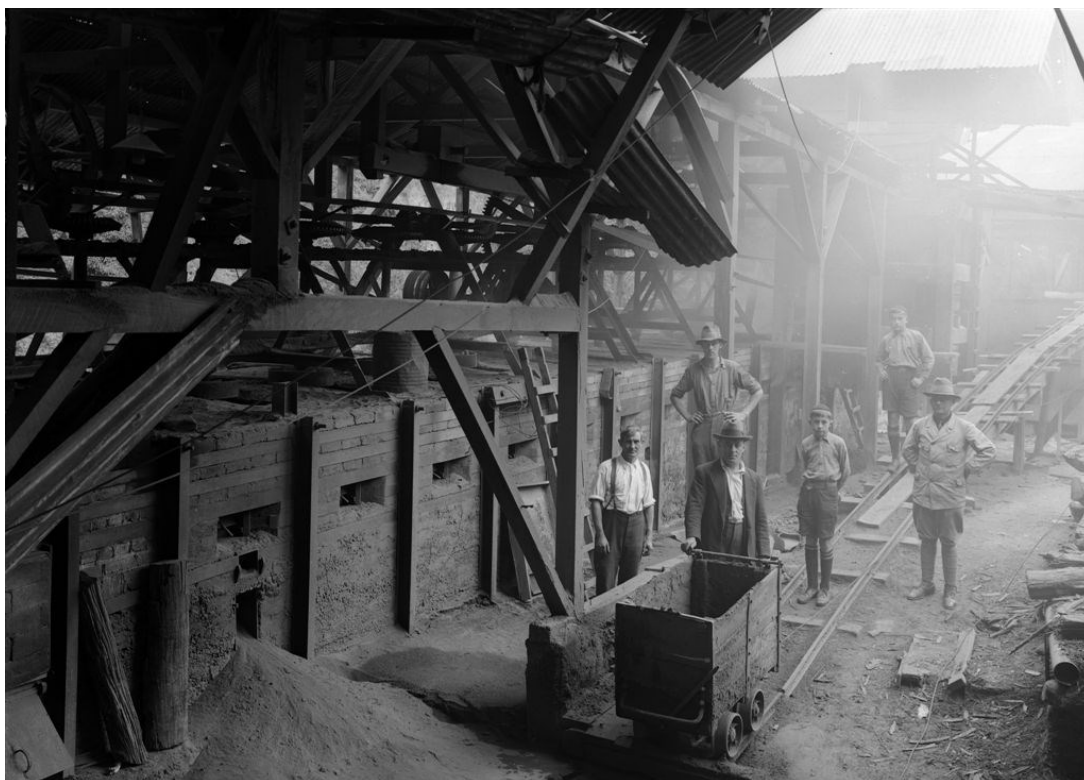
A launder took the sands to the Wilfley room, with seven Wilfley concentrators – inclined tables covered with heavy linoleum and narrow wooden laths, forming thin, tapering riffles (Fig 10). A lengthwise to-and-fro motion caused the denser grains (gold or gold-rich material and metallic sulphides) to be caught against the riffles, while the remainder (sands or pulp) flowed over them. The concentrates were then passed over two further copper amalgamating plates to catch any free gold. The remaining sand concentrates contained gold, mainly within sulphide grains, but initially could not be effectively processed in New Zealand. It proved too expensive to ship the concentrates to Australia, so they were stockpiled.



**Figure 10.** In the Wilfley room sands were washed across tables with riffles to concentrate heavier grains – largely gold and sulphides. The concentrates were again passed over amalgamating tables to catch any free gold, and then sent to the roasting furnace.

*Hocken Collection, S08-221p*

In 1924 an Edwards roasting furnace was installed at Snowy River (Fig. 11). The dark sand concentrates, containing a high proportion of sulphides were passed through the furnace, and agitated by a series of revolving arms. By the time the sand emerged some of the mineral components had been oxidised, which allowed higher gold recoveries treatment in the cyanide plant.



**Figure 11.** View outside the Edwards roasting furnace, on the Snowy River flats. Sands that have been roasted can be seen on the bottom left, and these were then transported to the cyanide plant.

*Alexander Turnbull Library, 1/2-233107-G*

### ***Cyanidation***

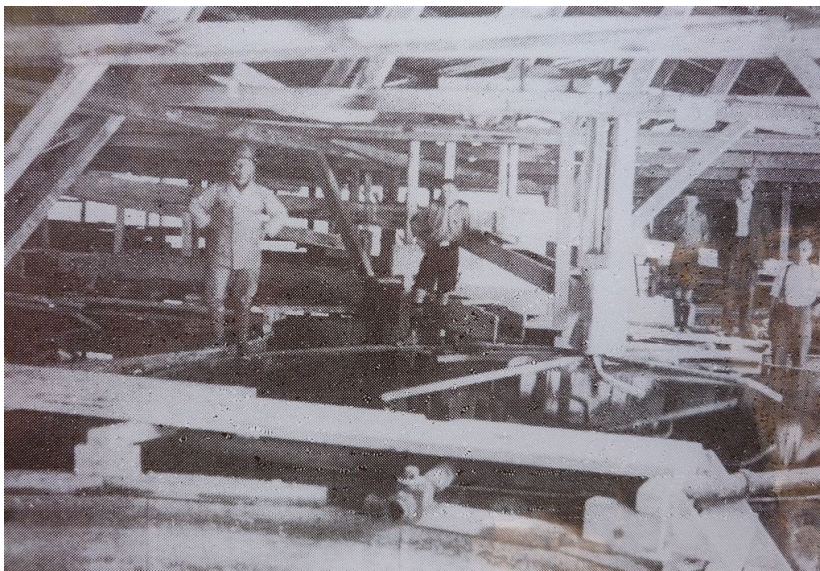
In the late 19<sup>th</sup> century it was realised that fine gold would dissolve in dilute cyanide solutions, and could be precipitated by reaction with zinc. By the time the Blackwater battery was built in 1908, cyanidation by the MacArthur-Forrest process had become a standard process to recover fine gold that had not been recovered by amalgamation (Fenby 1999, Park 1896). After Wilfley treatment and roasting, the remaining pulp and sands went through the cyanide process at the lowest part of the battery site, adjacent to the Snowy River (Fig 12).

The cyanide plant included 13 large steel vats. Sands from the spitzkasken and Wilfley concentrators as well as the roasting furnace were carried into the vats, and evenly spread by rotating distributors. The fluid was drained off through a calico filter in the bottom. The drain taps were then shut off, and a solution of 0.4% NaCN run in. As the cyanide solution percolated through the sands, the fine gold started to dissolve, and the solution was run off to the zinc room. Each vat load of sand was treated with cyanide three times, the solutions becoming progressively weaker. Finally, the sands were washed into the Snowy River.

Slimes from the spitzkasken were also treated by cyanidation in four 12 metre tall agitator tanks (Fig 12, centre). Compressed air was blown through the slimes in order to prevent an impervious layer forming, and it also maintained an oxygenated solution that was needed for gold dissolution. Settling and filtration were used to separate the dust-size slime particles, and once a clear solution was obtained it was treated in the zinc room.



**Figure 12:** View across Snowy River, close to river level, showing the cyanide tanks and associated buildings in the foreground, taken about 1914. The cyanide tanks were later roofed over. *Henderson (1917, p 172), Plate X*



**Figure 13.** Joseph Divis (left) and others standing on one of the cyanide vats, with rotating distributors in the centre. Unfortunately the original of this image cannot be located, and only a poor print is available.

*Department of Conservation, Hokitika*

### ***Zinc precipitation***

In the zinc room the gold-cyanide solution from the vats was run through partitioned boxes, each space containing a grating fitted with a central handle that was filled with zinc shavings (Fig. 14). Zinc reacted with the cyanide solution to precipitate a fine sludge rich in gold. This sludge was regularly washed out of the zinc boxes, treated with acid and dried ready for smelting.

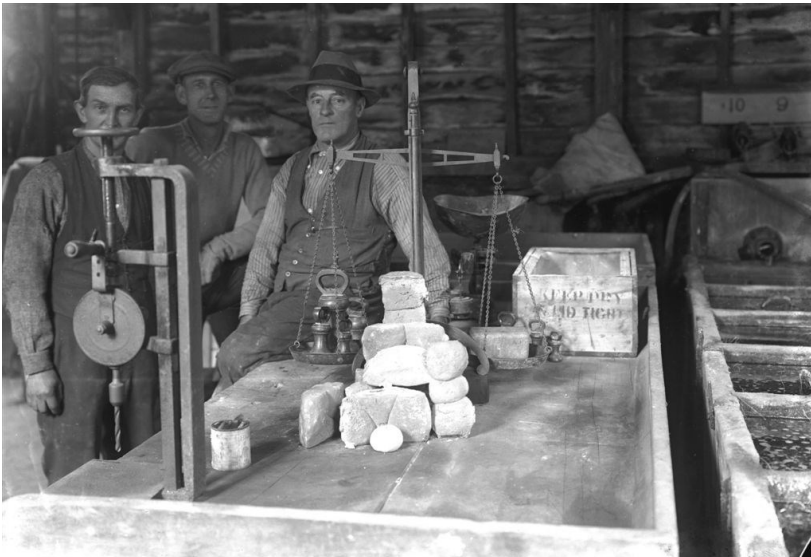


**Figure 14.** The zinc room, where the gold-cyanide liquid was piped through zinc boxes containing zinc filings. A thick slime rich in gold precipitated at the bottom of the boxes, and was collected regularly.

*Alexander Turnbull Library, ½-233322-G*

### ***Retorting and smelting***

The final stage of the process was to recover the gold, normally done monthly by the battery manager and senior staff. For mercury-gold amalgam it was a simple process to heat the amalgam in a retort to recover the mercury by condensation, leaving behind sponge gold (Fig. 15). This was melted at a higher temperature and the molten metal poured into moulds to form gold bars (Figs 16 & 17).



**Figure 15.** When amalgam was heated in a retort the mercury was driven off and condensed, leaving behind sponge gold, which was later refined. The white egg-shaped lump in the front is amalgam, while the others are sponge gold.

Scales in the background were used for weighing the gold while the drill at the left front was used to obtain samples for assay.  
*Hocken Collections, S08-221n*

**Figure 16.** The furnaces at the end of the zinc room were used to refine the gold sludge as well as the final refining of the sponge gold when it was melted and poured into gold bars.

*Alexander Turnbull Library, ½-233323-G*



**Figure 17.** The final result – a dozen gold bars, stamped BM for Blackwater mine – with Jack McEwin, Frankie Orr and Ted Allen keeping careful watch.

With each bar weighing 112 ounces, there is over \$NZ 1 million (2015 value) of gold on display.

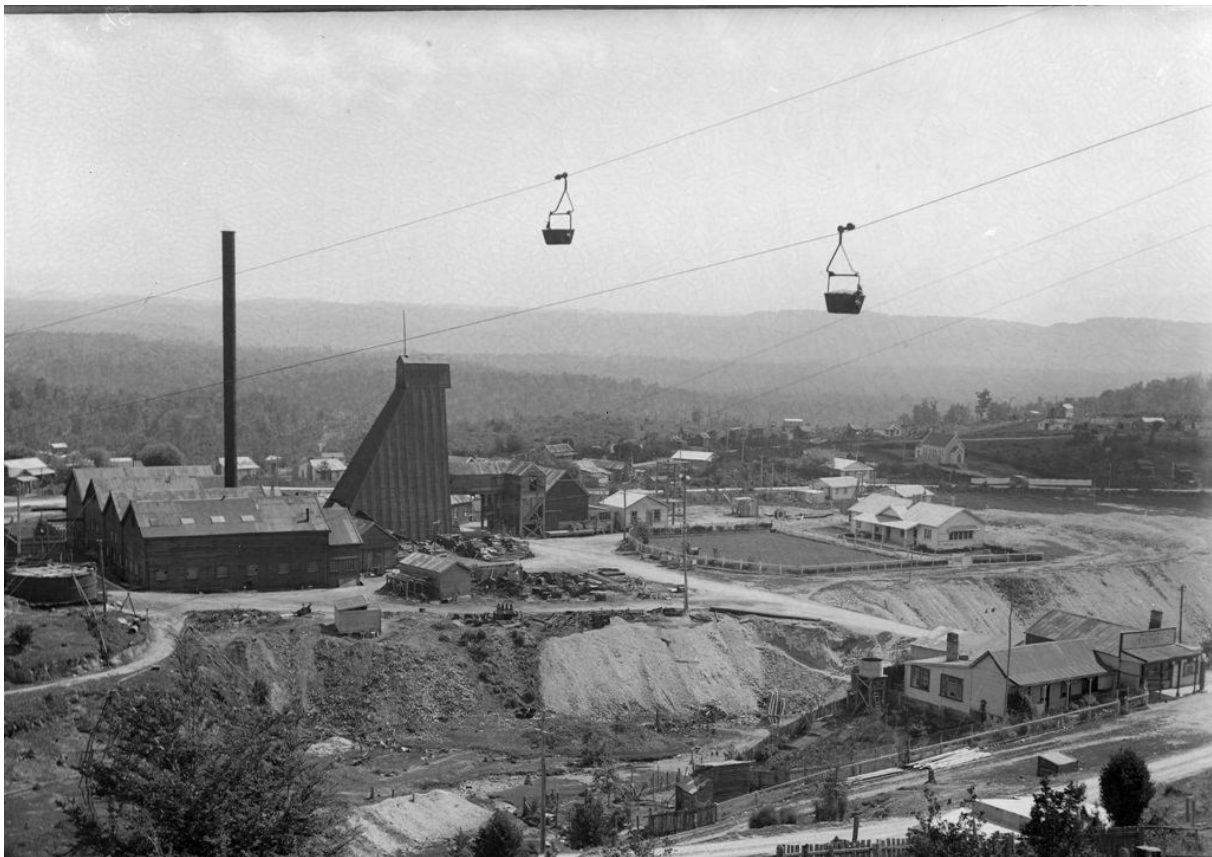
*Hocken Collections, S09-323e*



### Changes at the Snowy River battery

By the early 1930s mining had moved northwards from the Blackwater shaft, and it was becoming increasingly expensive and time-consuming to transport ore out of the original shaft. The Prohibition shaft, 600 metres to the north (Figs 1 & 2), was sunk to intersect the quartz reef, and mining gradually became centred there (although the Blackwater shaft was still used for pumping and ventilation). Although the rest of the world was suffering the effects of the depression, the price of gold increased, giving high returns to shareholders, and allowing the Blackwater Mining Company to make a considerable investment in new plant from 1933-38.

Initially a 1.6 km aerial ropeway was built to transport ore from the Prohibition shaft across the town of Waiuta to the Snowy River battery (Fig. 18). It became necessary to install additional stampers to deal with the increased production of ore, and the battery was working at maximum capacity.



**Figure 18.** Ore buckets on the aerial ropeway from the Prohibition shaft pass over the Blackwater shaft and the town of Waiuta on their way to the Snowy River battery.

*Alexander Turnbull Library, 1/1-39791-G*

In 1937 the mine management contracted a US expert, Mr Francis Blickensderfer to review the milling of the ore, and then to supervise the building of a new processing plant close to the Prohibition shaft. This incorporated new methods of ore processing - instead of stamp batteries, a ball mill was used to crush the ore, gold and heavy minerals were separated by flotation, and the cyanide process was modernised. The steps in ore processing at the Prohibition plant are described by Hutton (1947).



The new plant was commissioned in mid 1938, and the Snowy River battery was abandoned. The Edwards roasting furnace was moved to the new site, and most buildings and machinery from Snowy River was either re-used or sold as scrap. In 1940, after the battery had been largely dismantled, a water-driven power plant was erected on a new foundation to utilise the water supplies that had previously run the battery to provide electricity for Waiuta..

### **The Snowy River battery today**

The Snowy River battery is an important feature of the historic Waiuta town site, administered by the Department of Conservation. It can be reached on tracks from Waiuta or Snowy River. Although the native forest is regenerating and the buildings have disappeared, the footprint of the processing plant is still clear (Fig 19).

Impressive concrete foundations, built against the western wall of the valley, are the dominant feature of the battery site, and include the floors of most of the buildings shown in Fig 5. Many of the large iron tanks for the cyanide plant remain. In general most of what was directly on the ground remains, while most of the superstructure and equipment has been removed.



**Figure 19:** View across the Snowy River showing the remains of the battery in 2007.

*Photo, Les Wright*

## Environmental issues

An unanticipated effect of the installation of the Edwards roasting furnace in 1924 was contamination of the area surrounding the battery by arsenic. Contemporary accounts noted that the vegetation apart from bracken died with a radius of about kilometre of the oven (Morris 1986, p. 38), and the arsenic-rich fumes were cited as the reason why there was no wood borer in the buildings. Seventy years after the plant closed, there is some revegetation, but the area on the river flats near the roasting furnace is still bare of vegetation.

Both the ore and country rock contain small amounts of arsenopyrite, which is oxidised by roasting to form haematite, arsenolite ( $\text{As}_2\text{O}_3$ ), and sulphur dioxide. The arsenolite emerged as a vapour which spread over the surrounding area. Recent studies have shown that the unvegetated areas around the roaster are underlain by a light greenish-grey surface crust, up to 30 cm thick, enriched in arsenic. Reconnaissance arsenic analyses of surface materials were consistently above maximum recommended levels (0.02 wt %) (NEPC 1999; Haffert & Craw 2008). Signs warn visitors of the contamination near the roaster site (Fig 20), which has now been fenced off and capped with gravel.

In 2013 the government announced plans to remove the most highly contaminated material close to the Snowy River plant and the later Prohibition plant which is even more highly contaminated.



**Figure 20:** Sign near the site of the Edwards roasting furnace on the edge of Snowy River warning visitors of the danger of contamination. Arsenic is the main contaminant. Cyanide rapidly oxidises, and is unlikely to be a problem such a long time after the plant closed.

*Photo: S. Nathan*

## **Acknowledgements**

This paper is dedicated to the late Les Wright, who spent many years researching the history of Waiuta and the mining operations there. Les was very involved in plans to preserve the remains of the Snowy River battery as a heritage site as well as discussion on the problems of arsenic contamination.

The manuscript was reviewed by Bob Brathwaite, Judith Nathan, Mark Rattenbury and David Skinner, and they are thanked for their encouragement and helpful comments. The diagrams were drafted by Carolyn Hume.

## **References**

- Fenby DV 1999. Going for gold with cyanidation. Pp 199-209 in “New Zealand is different: Chemical milestones in New Zealand history”. Christchurch: Clerestory Press. 308 pages.
- Haffert L, Craw D 2008. Mineralogical controls on environmental mobility of arsenic from historic mine processing residues, New Zealand. *Applied Geochemistry* 23: 1467-1483.
- Henderson J 1917. The geology and mineral resources of the Reefton subdivision. New Zealand Geological Survey bulletin 18. 232 pages.
- Hutton GP 1947: Mineral dressing and gold extraction, Blackwater Mine, Reefton. AOSM thesis, University of Otago, Dunedin.
- Morris G (editor) 1990. Waiuta – the gold mine, the town, the people (2<sup>nd</sup> edition). Reefton: Friends of Waiuta, 141 pages.
- Nathan S 2010. Through the eyes of a miner: the photography of Joseph Divis. Wellington: Steele Roberts Publishing, 112 pages.
- Nathan S. 2011. Joseph Divis: mining town photographer. *Turnbull Library Record* 43: 117-128
- Park J 1896. The cyanide process of gold extraction (2<sup>nd</sup> edition). Auckland: Champtaloup & Cooper, 142 pages.
- Wright L 2007. Snowy River (Waiuta) – Historical Assessment. Report prepared for the Department of Conservation, Hokitika. 37 pages.
- Williams GJ 1964. Economic Geology of New Zealand. Melbourne: Australasian Institute of Mining & Metallurgy. 384 pages.