AUSTRALASIAN MINING HISTORY ASSOCIATION

PROCEEDINGS of the 22nd ANNUAL CONFERENCE

Building on the Mining Past

Cobar, New South Wales
16-21 October 2016

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Review Panel
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M.J. Davies
K.G. McQueen

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Front Cover Image:
View of the Cobar Copper Mine in 1874.
From J.E. Carne (1908) photograph by Frank Lean.

Sponsors 22nd Annual AMHA Conference

Message from the Mayor

On behalf of myself and the residents of Cobar Shire, It gives me great pleasure to welcome delegates to the 22nd Australian Mining History Association Conference. As Cobar approaches its sesquicentenary in three years, it is very appropriate that we host such a renowned event. Cobar’s mining history is one typical of the mining industry worldwide, boom and bust. However, today the mining industry in Cobar Shire is a great success and we hope that it continues well into the future.

Cobar Shire is a very significant player in the mining history of NSW and Australia and more importantly will be very much a part of the successful future of mining in Australia.
Whilst you are in Cobar I hope you have the opportunity to learn more about us.

Mayor Lilliane Brady OAM

AUSTRALASIAN MINING HISTORY ASSOCIATION

Presidents Foreword
Building on the Mining Past

On behalf of the AMHA Executive and the Conference Organising Committee I welcome you to Cobar for the 22nd Annual Conference of our Association. Our practice in recent years has been to hold stand-alone AMHA conferences in centres with a significant history of mining and Cobar, with both historic and operating mines in the vicinity, is the ideal venue for a conference on the theme *Building on the Mining Past.*

The Organising Committee has put together an impressive program of papers and field excursions. The wide variety of subject matter in the papers reflects the varied backgrounds and interests of our membership, a feature that contributes to the lively and stimulating atmosphere of the conferences.

The discovery of copper in 1870 was followed in later years by the development of silver-lead-zinc and gold mines, and Cobar became one of the most important mining districts in New South Wales,. With mining having been almost continuous for some 145 years, Cobar can claim to be the longest-lived mining centre in Australia.

This conference has been two years in the planning and has been brought about by the hard work of the Organising Committee consisting of Ken McQueen (Convenor), Adrian Hutton, Jenna Marett, Christopher Higgins, John Martin and John Collins. We should also not overlook the supporting role of our ever-vigilant Secretary-Treasurer, Mel Davies, operating remotely from Perth.

The conference would not have been possible without the enthusiastic support of the local community and I thank in particular the Cobar Shire and Mayor, Lilliane Brady. The Great Cobar Heritage Centre has generously provided access to its museum and outdoor exhibits related to the Great Cobar mine. I would also like to take this opportunity to express our appreciation for sponsorship from The Australasian Institute of Mining and Metallurgy, New Gold Peak Gold Mines, Glencore CSA Mine, Aurelia Metals and the University of Canberra.

We are fortunate to be able to make site visits to several current mining operations and for these we acknowledge the assistance and cooperation of the staff and managements of Aurelia Metals Ltd (particularly Stuart Jeffrey), Glencore C.S.A. mine (particularly Martin Scott and Jason Hoskin), New Gold Peak Gold Mine (particularly Chris Higgins)and Jenna Marett), and Mount Boppy (including Andrew Vigar and Reg Pretty).

A welcome addition to this year's program is a joint evening activity with the Cobar Branch of the AusIMM; particular thanks are due to Dan Steven for the organisation of this event. Other interesting activities will be a Cobar Heritage Walk with John Collins, and a Cobar Cemetery Walk with Kay Stingemore. As you can see, we are in for a busy, but fascinating week ahead!

Ross Both

Conference Program 16-21 October 2016

Day	Times	Activities and Locations
Sunday	6-8.30 pm	**Arrival and Ice Breaker from 6 pm** Pre-registration. Great Cobar Heritage Centre, Barrier Highway East Cobar.
Monday	8.00 am 9.00-10.30 am	Registration at Cobar Golf Club, Murray Street. **Welcome and Welcome to Country** Keynote presentation. Sandra Close *Gold in Australia*. Session *Cobar Mining - Introduction*.
	10.30-11.00 am	**Morning Tea**
	11.00-12.30	Session *Cobar Mining cont*. Cobar Golf Club. Poster session and Facebook discussion. Cobar Golf Club.
	12.30-1.30 pm	**Lunch**
	1.30-5.30 pm	**Local field trip:** Fort Bourke Hill - New Cobar open pit, then CSA gossan and mill **or** the Peak operations, finish at Old Peak historic site.
	6.30 p m	**Advisory Committee meeting**
Tuesday	8.30-10.30 am	**Inspection of Great Cobar site and museum.** Great Cobar Heritage Centre.
	10.30-11.00 am	**Morning Tea** Cobar Golf Club
	11.00-12.30 pm	Session *Mining People and Social History*. Cobar Golf Club.
	12.30-1.30 pm	**Lunch**
	1.30-5.30 pm	**Local field trip:** Mt Boppy - Canbelego.
	7.00 pm	**Mayoral Reception and Evening Lecture and Forum with AusIMM.** Invited Lecture: **Philip Payton**. Cobar Golf Club.
Wednesday	9.00-10.30 am	Session *Mining People and Social History cont.* Cobar Golf Club.
	10.30-11.00 am	**Morning Tea**
	11.00-12.30 pm	Session *Interesting Mining Events.* Cobar Golf Club.
	12.30-1.30 pm	**Lunch & book launch**
	1.30-3.00 pm	Session *Historic Mining Sites 1 – NSW.* Cobar Golf Club.
	3.00-3.30 pm	**Afternoon Tea**
	3.30-4.30 pm	Session *Historic Mining Sites 2 – Tasmania and W.A.*. Cobar Golf Club.
	5.00-7.00 pm	**Cobar heritage walk and buried pioneers.**
Thursday	8.30 am- 1.30 pm	**Field trip:** Mt Grenfell aboriginal paintings **or** McKinnons Tank gold mine (packed lunch provided).
	2.00-3.30 pm	Session *Historic Mining Sites 3 – Victoria.* Cobar Golf Club.
	3.30-4.00 pm	**Afternoon Tea**
	4.00-5.00 pm	**AMHA Annual General Meeting** Cobar Golf Club.
	6.30 pm	**Conference Dinner and Awards** Cobar Golf Club.
Friday	7.30 am- 6.00 pm	**Whole day field trip** (optional): Nymagee-Hera (packed lunch provided).

Schedule of Presentations

Monday		***Keynote and Cobar Mining*** **-** *Chair: Ross Both*
	9.30-10.00	'Gold in Australia: Production, price, processes and people' **Sandra Close**.
	10.00-10.30	'Mining the Cobar Mineral Field: An historical overview' **Ken McQueen**.
		Cobar Mining cont*. - Chair: Brian Hill*
	11.00-11.30	'The re-birth of the CSA mine, Cobar: A role for research' **Jim Enever**.
	11.30-12.00	'Edward Pigot, S.J.; Measuring earth tides at Cobar: A long and sorry failure' **David Branagan**.
	12.00-12.30	Poster 'The Great Cobar Explosion' **Elizabeth McQueen** and Facebook discussion **Rob Barnes**.
Tuesday		***Mining People and Social History*** *- Chair: Ruth Kerr*
	11.00-11.30	'Cobar Miners' Memorial' **Barry Knight and Kay Stingemore**.
	11.30-12.00	'Ye'll naa git me doon in ya pit' **Danny Spooner**.
	12.00-12.30	'Borgfeld to Billabong: Johannes Leberecht Noltenius - enterprise on Australian mining fields, 1855-1884' **Ross Both and Elizabeth Dunlop**.
Wednesday		***Mining People and Social History cont****. - Chair: Jim Enever*
	9.00-9.30	'Chinese tin mining in Australia and Malaya 1870s-1890s' **Paul Macgregor**.
	9.30-10.00	'Chinese gold seekers on the Western Goldfields of NSW' **Juanita Kwok** (Student Travel Grant winner).
	10.00-10.30	'The Chinese gold miners of Central West New South Wales: Their trials, tribulations and successes' **Barry McGowan**.
		Interesting Mining Events *- Chair: Greg Dickens*
	11.00-11.30	'Chillagoe to Cairns via Sunnymount: Still Oertling on' **Nicola Williams and Ruth Kerr**.
	11.30-12.00	'Potosi, Bolivia: Of the then and now' **John Ferguson**.
	12.00-12.30	'Comparing Australia's mining booms' **David Lee**.
		Historic Mining Sites 1 – **NSW** *- Chair: Nicola Williams*
	1.30-2.00	'The rise and fall of the Blayney Mines and Smelter Company's copper mine' **Meg Adams** (Student Travel Grant winner).
	2.00-2.30	'Commonwealth Oil Co., Newnes, New South Wales' **Leonie Knapman and Stephen Imrie**.
	2.30-3.00	'New South Wales opal: From beginnings to the atomic age' **Aert Driessen**.
		Historic Mining Sites 2 – Tas. & W.A. *- Chair: Wendy Carter*
	3.30-4.00	'Mining the Van Diemen's Land Company holdings, or digging yourself deeper in Tasmania' **Nic Haygarth**.
	4.00-4.30	'Entrepreneurial ambitions: Claude Albo de Bernales and the Western Australian Goldfields' **Mel Davies**.
Thursday		***Historic Mining Sites 3 – Victoria*** *- Chair: Mel Davies*
	2.00-2.30	'Whims, whips and loose-eccentrics: Winding technology on the Victorian Goldfields, 1851-1915' **Mathew Churchward and Peter Quinn**.
	2.30-3.00	'Springdallah: A mining community' **Joan Hunt**.
	3.00-3.30	'Sovereign Hill: If only this hill could talk' **Serena Ioannucci**.

Extended Abstracts

The rise and fall of the Blayney Mines and Smelter Company's copper mine

Meg Adams

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In July 2010, Alkane Resources, a multi-commodity mining and exploration company announced that gold deposits near Blayney represented one of the biggest finds in New South Wales. More recently, Regis Resources Limited acquired the McPhillamys Gold Project near Blayney and Newcrest, Australia's largest gold producer, expanded its external infrastructure at the Cadia East Gold and Copper Mine.

These projects and developments build on a long history of mineral exploration and development in and around the small town of Blayney in the Central West of New South Wales. One of the early mining ventures saw the formation of the Blayney Mines and Smelting Company's copper mine in the early 1900s (Fig. 1). This company grew out of earlier companies concerned with Blayney mineral works. With the prospect of extensive ore deposits, the flotation of the company on the London Stock Exchange, the commitment of members of the Collins House companies in Melbourne and the expertise of mining directors and engineers, why did the company fail?

This paper examines some of the networks that underpinned the formation and development of the Blayney Mines and Smelting Company and how the company was connected to several other mining and refining ventures in NSW such as Cobar, Dapto and Port Kembla. It draws on archival materials in NSW State Records, the University of Melbourne Archives and extensive newspaper accounts. The central argument is a simple one that seeks to show how seemingly disconnected mining ventures were part of a vast matrix of copper exploitation – Blayney is best understood by understanding this matrix.[1]

Figure 1. Remains of the Blayney Mines and Smelting Company copper smelter, Blayney NSW.

[1] J.E. Carne, *The Copper Mining Industry and the Distribution of Copper Ores in New South Wales*, 2nd Edition, Department of Mines, Geological Survey, Mineral Resources No. 6, 1908; P. Yule, *William Lawrence Baillieu: Founder of Australia's greatest business empire*, Hardie Grant, Melbourne, 2012, 423 pp.

Borgfeld to Billabong: Johannes Leberecht Noltenius - enterprise on Australian mining fields, 1855-1884

Ross A. Both and Elizabeth Dunlop

Johannes Leberecht Noltenius was born in 1831 in Borgfeld, within the Free Hanseatic City of Bremen in what is now northern Germany. At the age of 22 he left Prussia in search of opportunities elsewhere, firstly going to New York before following the example of his brothers Heinrich and Bernhard who had previously emigrated to Australia. He arrived in Melbourne in August 1854, at the height of the Victorian goldrush. After being employed for a little over a year in Bernhard's business in Melbourne, he joined the rush to the Fiery Creek goldfield – not as a digger but as the manager of a tobacco store. As the Fiery Creek rush began to wane he moved to Beechworth, again as a tobacconist.

Johannes' whereabouts are unknown from January 1859 until November 1866. Was this when he turned to mining? By late 1866 he had joined his brothers Heinrich and Bernhard, both of whom were by then in Adelaide, and soon thereafter was engaged as Manager of the Sixth Creek Gold Mining Company at Montacute, in the Adelaide Hills. When reports of discovery of the Barossa goldfield appeared in October 1868, Johannes promptly joined the rush and had early success in discovering a reef. He soon became an active and respected member of the goldfield's community and was elected a member of the Mining Board for the Barossa Goldfield. When the need arose for better crushing facilities he became Manager of the Victoria Quartz Cement Crushing Company, a position he later resigned to concentrate on his new discovery at Green Gully Hill. But the Barossa Goldfield was not a success and almost deserted by the end of 1870.

In February 1872 Johannes left with a party financed by the Northern Territory Gold Prospecting Association to explore for gold in the far north. Reef gold was discovered at Yam Creek by two members of the party, Harry Hauschildt and Harry Roberts. The Princess Louise Gold Mining Company was formed to work an adjacent claim, with Johannes managing the mine. In January 1874 the shareholders accepted a proposal by a group which included Roberts and Johannes to work the mine for 2 years on tribute. However, in November 1875 they advised the Directors of their intention to withdraw from the agreement because they lacked capital to continue sinking the shaft; the Company was wound up in February 1876. Meanwhile, Johannes had again become a respected member of the community, being appointed a J.P. whose duties included those of magistrate and coroner.

Johannes' next major venture came in 1878, when he and August Starke purchased the lease of the Extended Union Mine, which they worked jointly until Starke died *intestate* in 1881. The mine was then bought at auction by James Johnston and the Extended Union Gold Mining Company was floated, with Johannes and Johnston promoters, the latter becoming Manager. Although regarded as one of the best prospects in the Territory the mine was not profitable, leading to shareholder discontent and the resignation of both Johnston and Johannes.

In April 1884 Johannes accepted the invitation of his old friends Hauschildt and Roberts to visit them at the Daly River, where they were developing a copper mine. On the 3rd September the four men at the mine (Johannes, Roberts, another miner Landers and the cook Schollert) were attacked by Aborigines. Only Roberts survived; Johannes died of a spear wound while he and Roberts were attempting to make their way to the Daly River Cattle Station and he was buried beside a billabong that now bears his name.

Edward Pigot, S.J.; Measuring earth tides at Cobar: A long and sorry failure

David Branagan

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Just prior to the beginning of WW1 there began considerable interest in the study of possible deformation of the solid Earth by lunar-solar tide generating forces (analogous to the forces causing ocean tides). It was thought that useful information could be obtained by measuring the deflection of the Earth's surface at distances well away from the coast (to be free of the effects of oceanic tides). Measurements were to be made below the Earth's surface to reduce possible surface effects. A site chosen was near the outback NSW mining town of Cobar. However, it seems that W.G. Woolnough (1876- 1958), then Professor of Geology at the newly-established University of Western Australia was keen to be involved with measurements in the west.

Dr C.G. Abbot (Smithsonian Institution) was an early enthusiast, but the proposal for Australian involvement in this research came initially through Fr. Pigot's contact with George Darwin in 1912, and with the interest of the International Geodetic Association at Strasburg the same year.

The experiment involved the use of the horizontal pendulum using German equipment. This arrived quickly and with the help of Professor Leo Cotton, geophysicist at Sydney University, and others, was quickly installed at the Great Cobar Mine. Abbot also sent a geophysicist from the Smithsonian to support the research. However, Pigot was not satisfied with the early results and suggested improvements in the experiments. Then various matters intervened. Financial problems saw the mine closed and the equipment was dismantled and removed. Eighteen months later the mine was re-opened and the equipment was re-installed only to be hastily removed when the mine suffered flooding after torrential rains. Then the mine closed in 1919.

The local mining community came to the 'rescue' with another suitable site (the CSA mine). The site was at about the same depth and generally seemed to have better conditions. But all did not go well. Fire broke out in the mine's upper levels and the site was sealed, with the instruments inside and inaccessible. An attempt to reopen the mine saw the fires recommence and the instruments had to be abandoned!

Whims, whips and loose-eccentrics: Winding technology on the Victorian Goldfields, 1851-1915

Matthew S. Churchward[1] and Peter Quinn[2]

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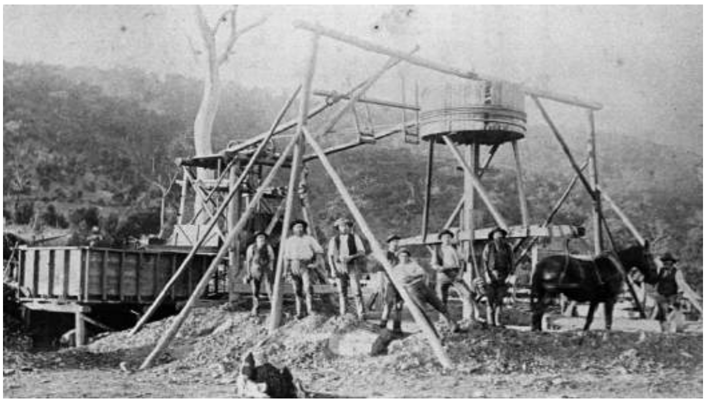
Winding technology was fundamental to the development of Victorian goldmining during the latter half of the 19th century, with both local and imported innovations enabling each successive wave of deep sinking. Winding gear was required for the raising of mullock, ore and washdirt, and almost equally importantly, for the baling of water to keep underground workings from flooding, and for safely raising and lowering miners, materials and equipment.

Throughout the 1850s and 1860s, most new developments in winding technology began on the Ballarat goldfields – the epicentre of Victoria's early mining activity and the pioneers of deep sinking. Tracing the rich alluvial leads or gutters across the gullies and creek flats of Ballarat East, then under the basalt plateau to the west, created challenges overcoming progressively increasing depths and heavy flowing underground aquifers. From the simple windlass, miners progressed to horse-powered whims and whips, then steam engines over a crucial 12 month period of 1854-55. Steam engines led to the adoption of winding cages and baling tanks (from 1856-57), and as depths approached 400 feet, a shift from round hemp and Manilla fibre ropes, to woven flat Manilla and wrought-iron ropes or patent chains (by 1859), then round iron wire ropes (by 1862) and finally steel wire ropes (by 1867). From Ballarat, the technologies spread to other mining fields, so that by 1870, 926 whims, 874 whips, and 1,100 steam engines were at work across the Victorian goldfields, with up to a third of the latter employed in winding – often in conjunction with other duties such as driving pumps, puddling machines or stamp batteries.

By the 1870s, quartz mining at Clunes, Stawell and Bendigo was at the fore of deep sinking in Victoria and many mines were replacing earlier single-cylinder geared winding engines with large twin-cylinder first-motion engines as shafts were pushed below 1,000 ft. By 1884, Victoria's deepest quartz mine had passed 2,400 ft and another fifteen mines exceeded 1,200 ft. The 1890s would see the introduction of a third generation of winding equipment with more powerful engines, steel poppet heads and additional safety features like steam or compressed air operated clutches and brakes, electric indicator discs and automatic warning bells. By 1900, Bendigo boasted the world's deepest goldmines with shafts of 3,000-4,000 ft, but over the following decade heavy drainage costs and declining grades would see the closure of many of the leading mines. After WWI, the mantle of Australia's deep sinking capital passed to WA.



Source: Museum Victoria.

Figure 1: A typical horse whim, Glenpatrick, Victoria, circa 1880.

Source: Museum Victoria.

Figure 2: Safety cage, safety hook, shaft gates and code of signals evident in this scene at the Berringa Mine, circa 1900, were all outcomes of the pioneering *Regulation of Mines Act, 1873*.

Gold in Australia: Production, price, processes and people

Sandra E. Close

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Australia has had three major gold booms, each with varying degrees of social and economic impact and technical innovation. The First Boom was 'low tech' but was instrumental in the spread of settlement in the country in the 1850s. Introduction of new technology plus new gold discoveries were the drivers of the Second Boom in the 1890/1900s, which also influenced an important socio-economic outcome.[1] The Third Boom, which began in 1982 and is still continuing today, is primarily the result of new technology, coupled with a new price regime. This modern boom, despite being by far the largest in terms of the amount of gold produced, has had little impact. For 2015, gold output was 285 tonnes or 9.2 million ounces, then worth around A$14 billion. Gold is one of Australia's single largest exports and Australia is the world's second largest gold producer after China.

The monetary role of gold, changes in the gold price and the effects of changes in exchange rates, which are fundamental elements in the story of gold, are briefly explored. The developments in ore processing which led to major technical changes in the gold sector and the resulting impact on the economics of gold production are examined in some detail. The focus is not only on the roles of cyanide and of carbon in gold processing, but also on the contribution of individual workers.

The use of cyanide and particularly the introduction in 1887 of the Cyanide Process for gold extraction, using dilute cyanide to dissolve gold and zinc to recover it from solution, is briefly covered before turning attention to the little known story of carbon. As early as the Second Boom, a few Australian workers were firm believers in the efficacy of combining cyanide and carbon in a new gold processing technique. While this was scoffed at by the international technical 'set', these local believers maintained their faith. However, it took almost a century before they were truly vindicated.

Using a combination of cyanide to dissolve gold and carbon to recover it from solution ultimately resulted in the modern CIP/CIL (carbon-in-pulp/carbon-in-leach) Process. The introduction of this process in the 1970s and early 1980s coincided with the complete decoupling of the link between gold and currency, as the price of gold was at last allowed to float freely on world markets. The combination of the new technology and the increase in the free-floated gold price, together with a range of other contributing factors, led to the Third or Modern Australian Gold Boom.

The first place the new CIP technology was introduced in Australia is little known but it is surprisingly close to Cobar.[2] The story of this plant and the various difficulties experienced by its owners and operators almost brings tears to the eyes.

[1] S.E. Close, *The Great Gold Renaissance*, Surbiton Associates, Melbourne, 2002, 281 pp.
[2] K. McQueen, 'The Mount Boppy Gold Mine, NSW: A leader in its day and more to come;. *Journal of Australasian Mining History*, vol. 3, 2005, pp. 74-96.

Entrepreneurial ambitions: Claude Albo de Bernales and the Western Australian Goldfields

Mel Davies

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Claude Albo De Bernales (1876-1963), a prominent entrepreneurial figure on the gold fields of Western Australia, was active in both the machinery and the gold mining industries. To explain his success as an entrepreneur, an attempt is made to identify the motivating forces that propelled him to float his Commonwealth Group of Companies on the London Stock Market in the 1930s.

One dominating force relates to his Basque-born great-great grandfather José Cayetano de Bernales, and also of his father Emmanuel Edgar Albo de Bernales, both of whom were endowed with exceptional entrepreneurial flare. His mother, Jane Emma Belden (1849-1932), also came from a wealthy American merchant family with connections in high circles, while in his young days he was linked through his father to such wealthy and influential American businessmen and entrepreneurs as George L. Pullman of railway fame; and financier, railway promoter and steel magnate, J. Pierpont Morgan (one of the so-called Robber Barons). While Claude's background would suggest a cossetted upbringing that gave him advantages and a head start in his activities, the evidence is that he had to overcome many serious obstacles to reach his goals. Such obstacles included a disjointed educational background that saw many interruptions to his training, and his often-frictional relationships with his father, but on the positive side there were socialising influences that made him a confident and ambitious member of the business community (Fig. 1).

After he took the London Stock Market by storm when floating his Commonwealth Group of Companies, de Bernales suffered the ignominy of seeing the companies struck off the London Stock Exchange. While this was much associated with jealousies raised because of his successes, his downfall does not negate his achievements. The paper does not touch on the orchestrated campaign that led to that situation, but one of the ironies of the history of the de Bernales' family is that before they died, both his great-great grandfather and his father also saw their ambitions crumble to dust.[1]

Figure 1: Claude Albo de Bernales as a confident young man.
Source: Dickson Papers, Iffley, Oxford.

[1] For further information on de Bernales' background and activities, see R.T. Appleyard, and M. Davies, 'Financiers of Western Australia's Goldfields', in R.T. Appleyard, and C.B. Schedvin (eds), *Australian Financiers: Biographical Essays*, Reserve Bank of Australia, MacMillan, Melbourne, 1988, pp. 160-189; Mel Davies, 'Claude Albo de Bernales – 'Wizard' of Australia's Golden West', in Raymond E. Dummet (ed.), *Mining Tycoons in the Age of Empire, 1870-1945, Entrepreneurship, High Finance, Politics and Territorial Expansion*, Ashgate, Farnham, UK and Burlington, USA, 2008, pp. 171-194.

New South Wales opal: From beginnings to the atomic age

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Australia produces more opal than any other country. Production began in 1889 on the Momba Pastoral Company's run 96km north of Wilcannia and 230km west of Cobar. The following year the New South Wales Department of Mines reported[1] that some 30 fossickers pegged 340 acres of Crown Land and that opal production in the first year was valued at £15,000. The opal field became known as White Cliffs, and by 1898 after families joined their husbands on the field, it had a population of 1200.

Government inducements encouraged fossicking further afield and in 1904 the Mines Department reported production from the Wallungulla district where the settlement of Lightning Ridge took root about 350km NNE of Cobar. Ten years later production from the Lightning Ridge district accounted for most of the New South Wales production. Production from both fields declined steadily to the years of World War II, the trend accentuated by periods of drought. From the post war years Australian production rose sharply, aided by more modern technologies. New production was nearly all from South Australia, but that is another story.

Nearly all opal in Australia occurs in deeply weathered profiles of sedimentary rocks that make up the Great Artesian Basin. These weathered profiles contain abundant silica, which commonly expresses itself as silcrete or 'billy rock'. Opal is another form of silica, obviously vastly different from amorphous silcrete and 'billy'.

Many people are unaware that humankind lives immersed in a sea of natural radiation. The source of such radiation includes unstable isotopes of various elements in the Earth, seeking to attain a more stable state by shedding energy. The particular isotopes that probably affect us most are isotopes of carbon (C^{14}) and potassium (K^{40}) which constantly irradiate us, even from within; uranium and thorium isotopes are also more widely known sources of radiation.

Around the early 1990s routine mapping and drill hole logging showed that the deeply-weathered profiles in which opal occurs showed higher than background levels of radiation. Further studies[2] showed the presence of anomalous concentrations of daughter nuclides emanating from the fission of naturally-occurring uranium. Subsequent gamma-ray logging of drill holes confirmed that radioactive haloes surround zones of opal formation and, furthermore, that the intensity of radioactivity increased with proximity to the central part of the opalised zone, whether of precious opal or non-precious opal. Around 2005 a small syndicate of adventurous and bush-loving folk deployed a gamma-ray logger to various mineral claims in the Lightning Ridge area and confirmed the efficacy of this technology to opal exploration.

[1] New South Wales Department of Mines Annual Reports, 1876-1964.
[2] Brian Senior and Lewis Chadderton, 'Natural Gamma Radioactivity and Exploration for Precious Opal in Australia'. *The Australian Gemmologist*, vol. 23, no. 4, October – December 2007, pp. 160-176.

The re-birth of the CSA mine, Cobar: A role for research

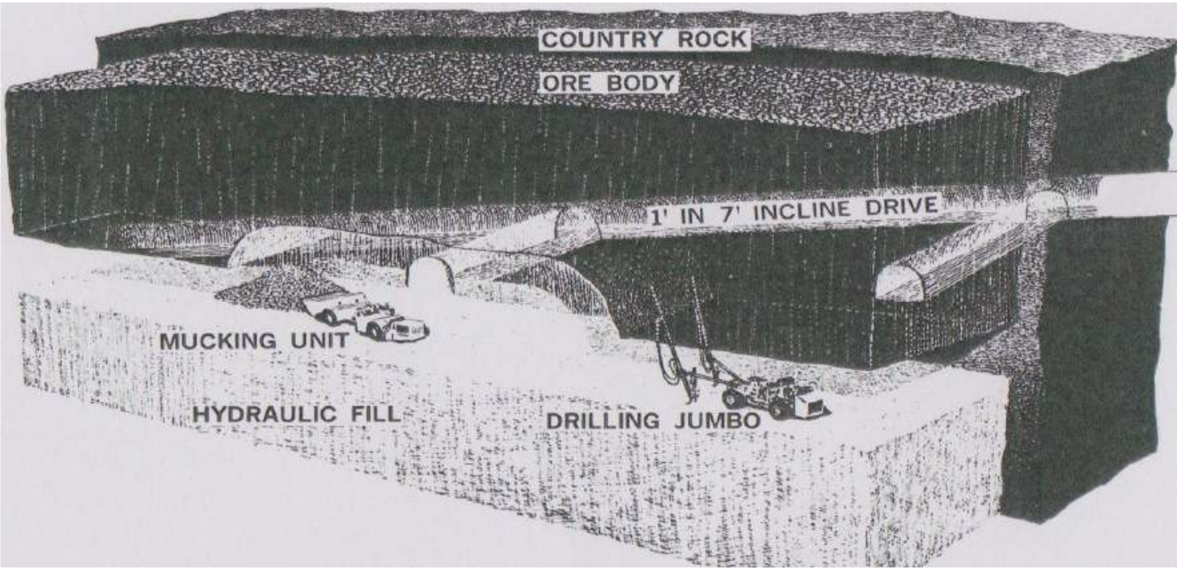
Jim Enever

CSIRO (retired), Australia

During the 1960s, Cobar Mines Pty. Ltd. (CMPL) oversaw the re-birth of the CSA mine near Cobar as a modern base-metal mining operation (primarily copper-zinc). The original CSA mine had been a feature of the Cobar field from the 1870s, until an uncontrollable mine fire saw its premature demise in 1920. The series of attractive ore bodies that were known to exist were, however, enough of an incentive to consider the development of a modern operation by the end of the 1950s. The challenge was taken up by CMPL in 1962.

The mining method selected for the re-development was over-head mechanised cut and fill stoping, employing hydraulic fill recovered from the ore processing plant (Fig. 1).

Figure 1: Over-head cut and fill stoping at the CSA mine, circa 1965.



Source: J.T. Brady, N.F.Owers and C.H.Annear, Ore Breaking and Handling at the C.S.A. Mine, Cobar, *Proc. Aust. I.M.M., No 229,* March 1969.

The geometry of the ore bodies dictated that the resultant final filled openings could be potentially of a height not previously contemplated in Australia. This fact led directly to a concern about the role of the fill in providing support to the stope walls. Further concern centred on the ability of the incrementally emplaced fill to support heavy mining equipment, and the potential for liquefaction of the fill brought on by vibrations created during blasting.

To address these concerns, a collaborative research project was established between CMPL and CSIRO to study the bearing properties of the emplaced fill and the response of the fill mass to environmental impacts such as blast vibrations. Other components of the research program focused on the stability of the rock surrounding the openings, and the interaction between the fill mass and the surrounding rock.[1] The outcomes of this research suggested that the chosen mining method was likely to be viable up to the full height of the stopes envisaged.

[1] For example, G.D. Attchison, M. Kurzeme and D.R. Willoughby, 'Geomechanics considerations in optimising the use of mine fill'. In *Jubilee Symposium on Mine Filling,* The Aust. I.M.M. Mount Isa, 1973.

Potosi, Bolivia: Of the then and now

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Potosi is a city and mining district high (4,000-4,800m) in the Andes mountains of modern day Bolivia. The Spanish rediscovered Potosi about 1545 after their conquest of the indigenous Incas. Due to its remoteness and high altitude, development was slow and always difficult. The bare, conical cone of an extinct volcano was named the Cerro Rico (Rich Mountain) because of its prolific content of silver. By about 1600 Potosi reached peak production of silver, at about 200 tonnes per year, and was the world's largest industrial project. Silver returned to Spain made it a European power and the silver peso or piece- of- eight became global currency. 'Vale un Potosi' (Worth a Potosi) remains a catchphrase for untold mineral wealth.[1]

The Spanish crown wanted silver and assisted the development of mining and ore treatment. Viceroy Toledo designed the colonial 'mita' system to provide forced Indian labour to the mines, supported the supply of mercury for silver processing, provided subsidies and the development of supply routes. In return, the Crown imposed a tax referred to as the Royal Fifth (later reduced to a tenth). Silver was transported back to Spain via the long 'treasure trail', from Potosi, Lima, Panama, to Seville, involving llamas, mules, slaves, galleons and pirates.[2]

The cold patio process of mercury amalgamation of silver ore was adopted at Potosi from about 1570. While actual mining remained a crude extraction process, amalgamation was progressively refined and silver production increased. The supply of mercury became vital and limiting. Initially mercury was sourced from Almaden in Spain at great cost, before production at Huancavelica in Peru.[3]

Silver production went into long decline from the mid-1700's, as did Potosi. Tin production became important at Potosi during the 20th century. Today mining of various metals continues, but on a small scale.[4] The city of Potosi has been proclaimed a UNESCO World Heritage Site and attempts are being made to preserve the integrity of the mountain peak. Underground mining tours are available for the adventurous.

Potosi has a long, rich mining history and was a major source of silver to the world. The debate continues on the conundrum of comparing the value of production and development versus the costs in human life, social structure and environmental damage.

[1] Kendall W. Brown, *A Mining History of Latin America from the Colonial Era to the Present*, University of Albuquerque, 2012; Wendell E. Wilson and A. Petrov,'Famous Mineral Localities: Cerro Rico de Potosi Bolivia', *The Mineralogical Record*, vol. 30, Jan.-Feb. 1999, pp. 9-36.

[2] Rose Marie Buechler, The Mining Society of Potosi, 1776-1810. Syracuse University Press, 1981.

[3] Wendell E. Wilson, and A. Petrov,'Famous Mineral Localities: Cerro Rico de Potosi Bolivia', *The Mineralogical Record*, vol. 30, Jan.-Feb. 1999, pp. 9-36.

[4] *Ibid*.; R.H. Sillitoe, C. Halls and J.N. Grant, 'Porphyry Tin deposits in Bolivia'. *Economic Geology*, vol. 70, 1975, pp. 913-927.

Mining the Van Diemen's Land Company holdings, or digging yourself deeper in Tasmania

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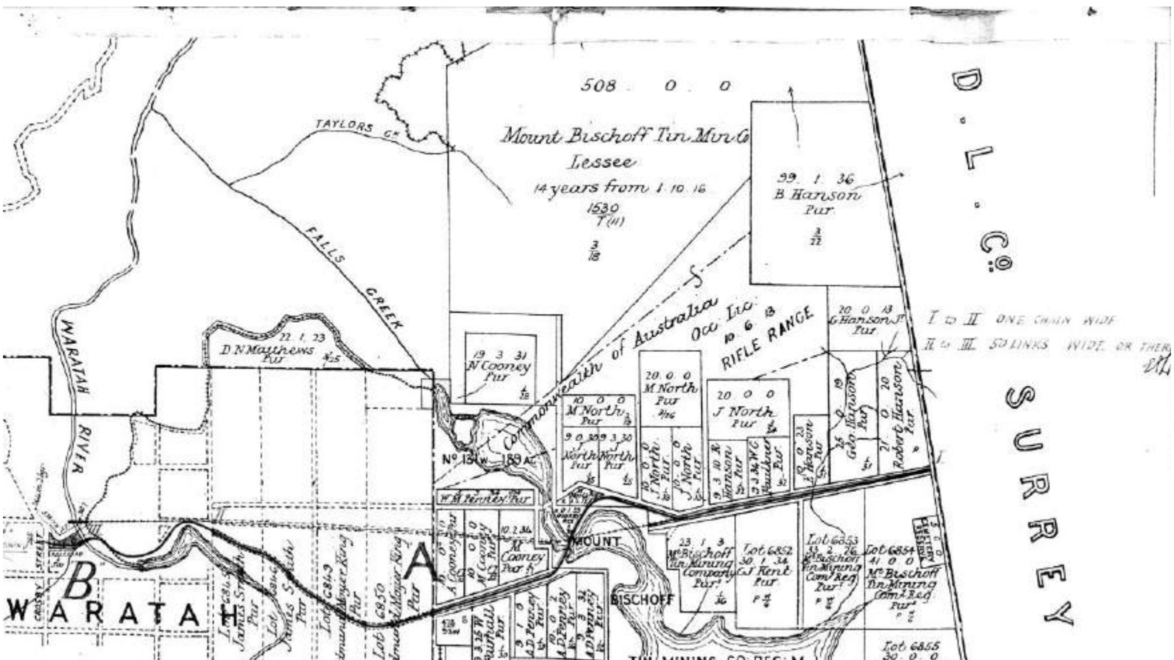
The Van Diemen's Land Company (VDL Co), established under royal charter in London in 1824, was or is one of England's longest-running colonial enterprises. Although now primarily Chinese owned and a dairy farmer, it initially aimed to grow fine wool for the European market in Van Diemen's Land (Tasmania). Its wool-growing operations in that colony were so disastrous that by the time of the New South Wales and Victorian gold rushes in 1851 it was preparing to withdraw all stock and become an absentee landlord. The company's efforts to diversify its income stream by exploiting its own mineral deposits and the mining trade were generally farcical. It was bad luck that the VDL Co's major holding, the 150,000-acre Surrey Hills block (Fig. 1), was capped with a layer of basalt that obstructed prospecting, that the company omitted the Mount Bischoff tin deposits from the Surrey Hills block and that the Kara scheelite mine was established after the company sold this land. However, direction of the company from London was perhaps a bigger hurdle, helping to ensure that it remained a spectator during Tasmania's late 19th-century mining boom. The Emu Bay Railway established by the company to exploit the west coast mining trade took nearly 90 years to pay a dividend. Two rich mining heritage sites, the Hampshire silver mine and the Mayday hydraulic gold mine, remain from the VDL Co's digging days.

Figure 1: A section of the county chart placing the VDL Co's Surrey Hills block boundary just outside the town of Waratah and the Mount Bischoff tin mine.



Source: From VDL22/1/20, Tasmanian Archive and Heritage Office

Springdallah: A mining community

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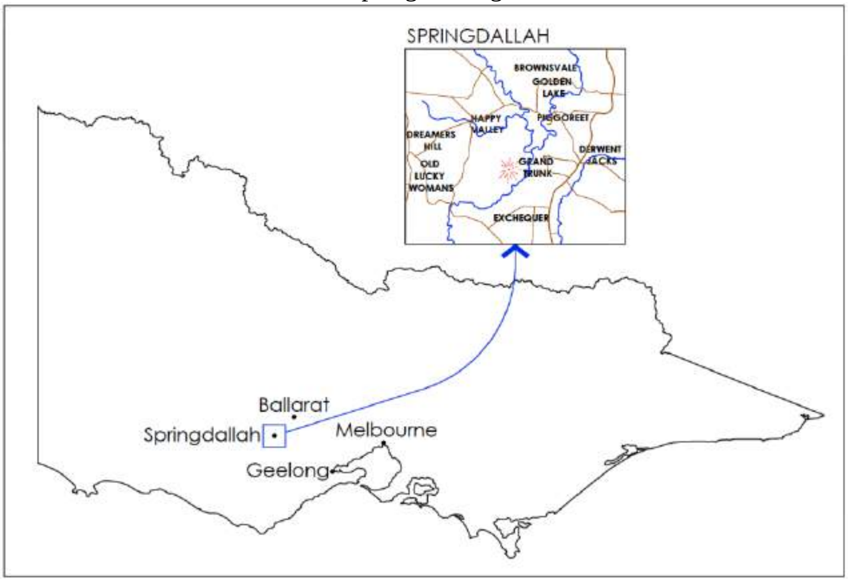
The discovery, rise, progress and gradual decline of the Springdallah goldfield, 30km south-west of Ballarat in Victoria (Fig. 1), spanned several decades. Close to Linton township, Springdallah was part of the extensive span of goldfields industry along the Woady Yaloak Creek. A network of nine communities enjoyed prosperity and productive success in the 1860s and 1870s, relying totally on the deep lead gold mining industry.[1]

Figure 1: Location of the nine communities of the Springdallah goldfield in Central Victoria.



Source: Map courtesy of Stephen Hunt.

The main Springdallah townships of Piggoreet and Happy Valley were the thriving commercial centres servicing the goldfield. Little material evidence survives today other than mullock heaps and springtime clumps of daffodils and agapanthus dotted about the paddocks. Unlike the many regional histories that celebrate growth from goldfields to city status, this paper focuses on the miners who worked the deep leads of buried river beds, and how they and their families effected material and social change to benefit the communities they created. It explores family formation and community building, and highlights the social, cultural, domestic and economic life of the extended mining families residing at their industrial workplace on the mid-19th century Victorian goldfields.

This paper, based on a PhD thesis, reveals that, in contrast to the strong Cornish presence on many Victorian goldfields, miners at Springdallah came mainly from northern England, south-west Ireland, and the lowlands of Scotland, often with extensive kinship networks.[2] As the goldfield was gradually worked out, many miners took advantage of Victorian land legislation, particularly the 1869 Land Act, to take up farming properties both locally and in the north and east of the State.

[1] T. Dicker, *Dicker's mining record and guide to the gold mines of Victoria*, volume III, Thomas Dicker, Melbourne, 1864, p. 221

[2] Janice Croggon and Joan E. Hunt. 'The Scots at Springdallah', *Provenance: The Journal of Public Record Office Victoria* 13 (2014).

Sovereign Hill: If only this hill could talk

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Sovereign Hill is an award winning, internationally acclaimed museum attracting huge audiences to a regional centre, sustaining a gold rush that clearly never ended. In 2015 Ernst and Young Australia, reported on the museum's economic contribution and benefit to Ballarat and the surrounding region indicating staggering results. In the 2012-2013 financial year, SHMA generated 60,000 bed nights and contributed AU$228.5 million and 1,422 jobs directly and indirectly to the Victorian economy.[1] Yet little is known of the historical mining sites located within the museums boundaries.

Discovery of the Canadian Nugget (1,319 ozs) in 1853 sparked a rush to the Canadian Lead at the southeast corner of Sovereign Hill. Significant alluvial gold finds were consistently made for quite some time including the Durham Hole (located under the SHMA Entrance Building) famous for producing 12,240 oz of gold in one year (1856).

In 1859 a 16 head battery, known as Peake's battery, was installed and a dam dug to service the machine. This dam remains as a delightful picnic area and is now referred to as the Post Office Dam because in 1861 the Post Office Hill Company purchased the lease and battery. The Speedwell Mine was also started in 1859, with the No.1 shaft sunk slightly north of the Gold Museum entry. A third shaft was sunk in 1895 and later the mine was purchased by the famous Madam Midas and reformed as the Normanby North, not a very successful mine wound up in 1911. This mine can be visited by when taking a guided mine tour. Its old mullock heap is currently part of the surface workings within the outdoor museum. A small, independent tributers mine, located near the present candle making works, can also be visited. Sections of the old stopes are believed to reach the No.1 Plat of the Normanby North mine.

The Sovereign Company mine was reformed from the Ballarat East Company in 1868, but yields were poor and it was let to tributers. Its shaft was located at the lookout tower and is the highest point of the outdoor museum. Although not a very successful mine, we believe Sovereign Hill retained the name because of the location. In 1930 the tailings dam was turned into the Golden Point Swimming Pool, an important and beautiful public space. It is rumoured that many Ballarat families brought their 'yank' during WWII to the lookout as a local attraction[2]. The lookout remains and the swimming pool is located under the SHMA Hotel.

The New Normanby Mine was formed in 1879 and ceased operations in 1917. The ruins remain near the SHMA horse stables and it is planned to open the site for public viewing soon. Also in 1879, the Pearse brothers sank a shaft that later became the North Woah Hawp mine, and which operated successfully until 1918. What remains is located on the south side of the SHMA site, with the main shaft currently used by Castlemaine Gold for ventilation. During the 1930s, cyanide works were established and tailings from the New Normanby mine were reprocessed. Further mining also took place during this period with two adits being driven into the side of Sovereign Hill. One of these adits was later widened for our underground train tunnel.

With all this wealth of mining history over 85 acres, Sovereign Hill is a prime example of how a community can successfully build on its mining past.

[1] Ernst & Young Report Summary, www.sovereignhill.com.au/media/uploads/Rush_Issue1_2015.pdf, pp. 20-22.
[2] M. Greville, Golden Mount Progress Association, letter to Members of the Ballarat Historical Society, 1947.

Commonwealth Oil Co., Newnes, New South Wales

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[1]Author and Historian, Mittagong, NSW, 2575
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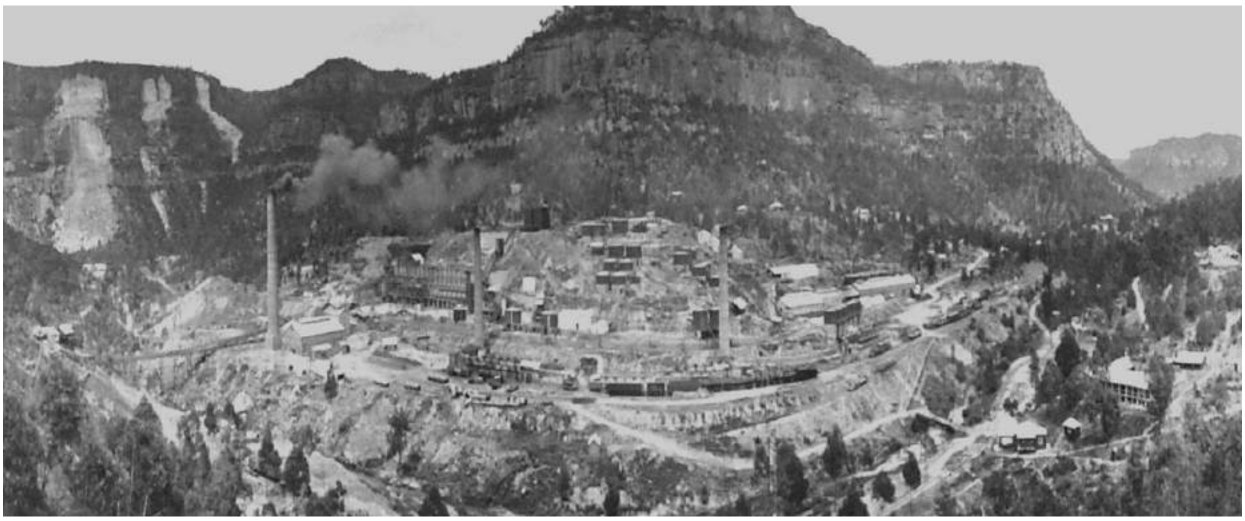
Newnes is located in the Wolgan Valley in the northern Blue Mountains of NSW, Australia. The Valley was accessed through Lidsdale on the Mudgee Road some 13km from Lithgow. Kerosene shale mining started in the Wolgan Valley in the 1870s, when packhorses carried the shale to Sydney. There were numerous mining leases throughout the valley, but it was not until 1905 that large scale mining developed when the Commonwealth Oil Corporation (COC) took up mining leases in the Wolgan and Capertee valleys. The Wolgan Valley site was named Newnes South and the Capertee Valley site Newnes North. The shale was of a better quality in the Capertee Valley, but transport from here was a major problem. Newnes South was more accessible with better transport from the east at Newnes Junction to markets and it became one of the largest oil shale operations in NSW.

The COC works (Fig. 1) contained crude oil stills, retorts, fractionating plant, heavy oil stills and a complete paraffin wax factory. The refinery operations included acid and alkali washing, redistillation to produce various grades of kerosene and fuel oil. In addition to the primary oil plants, there was a complete candle making and boxing establishment, and an ammonium sulphate plant. The company had its own power station and brick works. It also had a coke works, which supplied coke to the iron smelter at Lithgow and the copper smelter at Cobar. The sale of coke provided an early source of cash. The company built a railway around the plant and to the Government Main Line at Newnes Junction, 50km away. This railway was built through some of the most rugged country in the Blue Mountains and required the use of a special type of locomotive. The railway line construction was an engineering feat.

In 1937 Newnes North was renamed Glen Davis and the National Oil Pty Ltd company took over to produce petrol during the Second World War. The plant was closed as soon as the war ended.

Figure 1: Commonwealth Oil Corporation works at Newnes (South).



Source: Bill Goodwin photo collection.

Cobar Miners' Memorial

Barry Knight[1] and Kay Stingemore[2]

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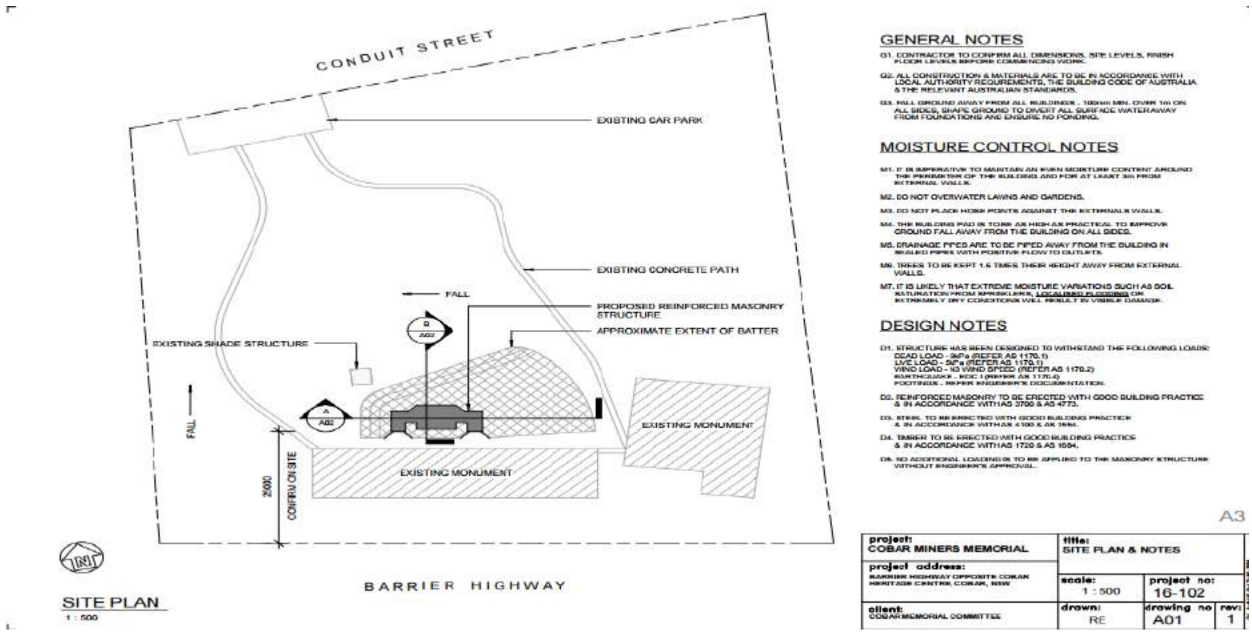
The Knight family came to Cobar in 1871 from South Australia, the year the Great Cobar Copper Mine was founded. They have been graziers, miners, wood-cutters, Alderman and Councillors, tank-sinkers, businessmen - we've had a crack at everything. I was a Councillor from 1988 to 2000. I am a Knight and an Iron-ringer.

Copper was discovered in Cobar in 1870. In the last 146 years, some 181 people have lost their lives working in the mines, while numerous others died as a result of industrial illnesses. They died in 24 mines: The Great Cobar Copper Mine, the Great Central, Nymagee, Hard-to-Find, Lucky Step, Great Tarcombe, Occidental, Maroumba, Fort Bourke, Giralambone, Chesney, Cobar Gold Mines, Crowl Creek, CSA, The Peak, Shuttleton, Mount Hope Mine, Elura, Mount Boppy, Bonnie Dundee, Overflow, New Occidental, New Cobar, and the Diane Mine. Further research will determine how many were buried in local cemeteries and how many taken home. Fewer than half of those interred locally have headstones or any sort of marker.

The earliest recorded mine death happened on 17th February 1880, one Henry Woods, aged 24. The most recent was in 2014. It is important to the community to acknowledge, remember and honour those who have died, as it is part of the identity of Cobar.

Although the CSA Mine has a memorial with the names of all those who have died in that mine, there is currently no community memorial. The Cobar Miners' Memorial project aims to correct this situation.

Figure 1: Location plan for proposed Miners' Memorial, Cobar, NSW.



Source: Central Queensland University, 2016.

Chinese gold seekers on the Western Goldfields of NSW

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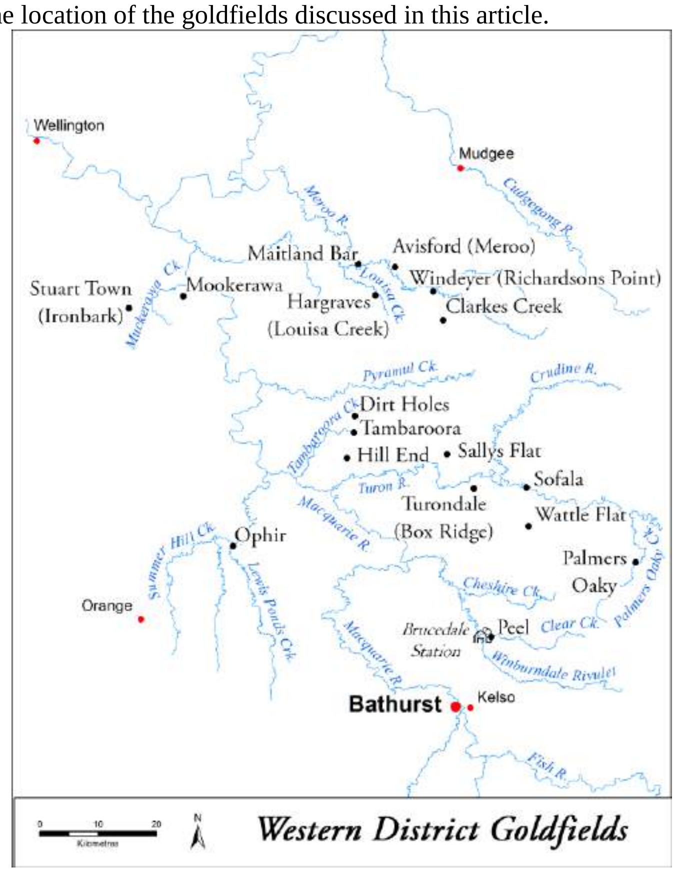
It was in July 1856 that the *Bathurst Free Press* first remarked on large parties of Chinese passing through Bathurst on their way to the Western Goldfields of New South Wales. However, there are reports of Chinese on the Western Goldfields as early as 1851. Chinese settlements at new gold fields at Tambaroora, Sofala, Louisa Creek contributed to the development of towns in those places, but little research has been done on the lives of Chinese individuals within those communities and how they interacted with the broader gold field communities.

My PhD research into the Chinese in the Bathurst district (Fig. 1) distinguishes between the Chinese from Amoy (Xiamen) who were on the goldfields in small numbers before 1855, and the Chinese gold seekers from Canton (Guangdong) who arrived after this time, establishing stores and communities on the gold fields and in goldfield settlements in the Bathurst district. In this paper I discuss early Amoy diggers on the goldfields, focusing on the role of the Colonial Gold Company in importing Amoy labourers to work on the Great Nugget Vein at Louisa Creek and the Wentworth Goldfields Act" (the Gold Fields Management Act, 1852, 16 Vic. No.43) as a response to Chinese indentured labour. I also discuss sources that inform us about the lives of Cantonese gold seekers on the Western Goldfields, in particular the 1858 Report of the Select Committee on the seizure of gold from the *Ethereal* and *Mary Nicholson*; Chinese petitions for restitution following the Lambing Flat riots and Mew Chip's Gold Remittance Book, which records gold dust and gold sovereigns carried back to villages in China between 1866 and 1890.

Figure 1: Map showing the location of the goldfields discussed in this article.



Source: Adapted from Map 2: Western goldfields of the Bathurst – Orange- Mudgee area, in Matthew Higgins, *Gold and Water: A history of Sofala and the Turon Goldfield*, Bathurst: Robstar Pty Ltd, 1990.

Comparing Australia's mining booms

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This paper compares the mining boom that began in the early 1960s and continued through to the end of the China resources boom in 2012, with the gold rushes of the nineteenth century. The discovery of gold in 1851, argues economic historian Ian McLean, 'delivered a major shock to the predominantly pastoral economy of Australia and ushered in a dramatic episode in the country's prosperity'.[1]

The economic consequences of the gold rush did not last a mere number of years. They lasted for about half a century. McLean argues that it is appropriate to look at the entire half-century from 1851 to 1900 'as a single era of economic expansion, rapidly increasing population and rising incomes' substantially influenced by the mining of gold in New South Wales, Victoria, Queensland and Western Australia.[2]

The author argues that we may look at the period from the early 1960s to 2012 as a similar epoch in which Australia was transformed by a renaissance in mining. A 'second rush' began unexpectedly with the development of new export industries, the most prominent of which were coal, iron ore and bauxite. Australia's move to greater economic openness began well before the 1980s, with the 1957 Australia–Japan Agreement on Commerce, the end of the export embargo on iron ore, federal subsidisation of coal ports on the eastern seaboard and the wave of industrialisation across Australia that accompanied the development of bauxite. The 'second rush' continued in the 1970s, despite rising oil prices, with the 'resources boom' from 1977 to 1982. Despite a downturn in mining globally, mining remained a vitally important sector of the Australian economy in the 1980s and 1990s before embarking on the most dramatic period of boom conditions between 2002 and 2012.[3]

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[1] Ian W. McLean, *Why Australia Prospered: The Shifting Sources of Economic Growth*, Princeton University Press, Princeton, 2013, p. 81.
[2] *Ibid*., p. 82.
[3] David Lee, *The Second Rush, Mining and the Transformation of Australia*, Connor Court, Redland Bay, Queensland, 2016, 463 pp. ISBN 978-1-925501-14-8.

Chinese tin mining in Australia and Malaya 1870s-1890s

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From the early 1870s, alluvial tin mining attracted thousands of Chinese to three key fields in eastern Australia, centred on Tingha in New England, NSW, Stanthorpe in southern Queensland and Weldborough in Northeast Tasmania. The scale of this mining endeavour rivalled the more well-known Chinese gold rushes in Australia, yet in Australian history, the Chinese tin story has received much less attention than Chinese and gold. As alluvial tin mining used similar techniques to alluvial gold mining, it would be expected that Chinese attention would turn to tin as much as gold when the increasing tin price in the early 1870s created a number of tin rushes around Australia. The key characteristics of most Chinese mining endeavour in Australia and Malaya were low capital input, and high labour input, complemented by traditional agricultural expertise in cooperative water management brought from China. The particular Chinese skill in managing labour was to: work in large teams, with a strongly developed division of labour; have these teams work large areas; apply systematic extraction across a site; and to work a field methodically until most of the ore (or metal) had been acquired. A common description of the approach of Chinese goldminers in Australia was that they could make poorer fields pay, and work them profitably for longer periods; similarly with tin.

In 1877 for instance, at Vegetable Creek in New England, 'the difficulty experienced by Europeans in working the poorer shallow grounds profitably…paved the way for the coming of the Chinese…the greater part of the shallow tin ground being let to the Chinese on the tribute system'.[1] The tribute system, which was also commonly used by European miners, provided for the working men to work the tin themselves, paying all the expenses of the extraction and cleaning of the tinstone, and receiving in return an agreed price per ton from the companies who held the claims. This approach, giving the Chinese freedom to apply their own extraction methodology, enabled their large scale productive methodology to prove superior to the smaller scale practices followed by European tributers, particularly when the tin price dropped and water supply was poor, as was the case during the drought of the late 1870s. Chinese expertise in efficiently building dams enabled them to spread the meagre rainfall over longer work periods across the year. Thus by the early 1880s, Chinese labour came to dominate the shallow workings on many Australian tin fields. They were then in prime position to benefit from the fortunate return of better rainfall and an improved tin price. Chinese recognition of this fortune is evidenced by the many commemorative plaques dated 1883 that were erected in the temples of Weldborough, Garibaldi, Moorina, Gladstone and Lefroy, five of the tin towns of NE Tasmania.[2]

Yet the scale of Chinese tin mining in Malaya at the same time dwarfed their Australian activity. In 1883, Chinese miners made Malaya the world's number-one tin producer, and by 1903 there were 223,000 Chinese involved in tin mining in Malaya.[3] The abundance of tin ore in Malaya partly explains this, but also the abundance of water and large constantly flowing streams in a wet tropical environment, allowing Chinese labour productivity and water management to be engaged on a major, consistent and expansive scale.

[1] T. Edgeworth David, *Geology of the Vegetable Creek Tin-Mining Field, New England District, New South Wales,* Charles Potter, Government Printer, Sydney, 1887, pp. 7-8.
[2] Chinese Temples collection, Queen Victoria Art Gallery & Museum, Launceston.
[3] Leanne Power, Chinese Labour in the Malayan Tin Mining Industry - An Historical Perspective, c. 1800-1948, Masters thesis, University of New England, 1996, p. 109.

The Chinese gold miners of Central West New South Wales: Their trials, tribulations and successes

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The experiences of the Chinese miners in Central and Central West NSW outside of the major goldfields, such as Hill End, Sofala and the Turon generally, are little known.[1] However, the Chinese miners were among the first miners on the Ophir goldfield in the early 1850s, and on other nearby goldfields, such as Coombing Park, near Carcoar.[2] The main wave of Chinese miners in Central West NSW (here defined by the boundaries of the Orange, Blayney and Cabonne Shires), however, came in the late 1850s and early 1860s. They were some of the first miners at King's Plains, and were the first miners to discover large payable deposits of alluvial gold on the Belubula River near Carcoar. For many years the Chinese miners were in the majority on the Belubula River diggings and King's Plains.[3] The Belubula River diggings were the main goldfields in the Carcoar district and Central West NSW, but it is only in the last few months that their location has been verified. For the most part they have been a diggings in name only - now they are an identifiable place as well.[4]

I outline the Chinese experiences on these goldfields, the archaeology and topography of the diggings, the circumstances leading to the re-location of the Belubula River diggings, local accounts of other lesser known goldfields, and the attitudes of local residents to the Chinese miners. Local reactions were a mixture of bewilderment, prejudice and gratitude.[5] The Chinese miners were seen as an easy target by bushrangers such as John Piesley and Frank Gardiner, particularly when commuting to the Abercrombie diggings further south.[6] Nevertheless, some residents were very positive, especially the storekeepers and traders, for the Chinese miners provided a significant boost to the local economy. Subsequently, many of the miners settled in the district, taking up occupations such as market gardening, and becoming a very important element of their local communities.[7]

[1] Barry McGowan and Genevieve Mott, *A Thematic history of the Chinese People in the Orange City, Blayney and Cabonne Shire Councils*, submitted to the Orange Shire Council, June 2016. The impetus for this paper arose from the aftermath of the afore-mentioned thematic history, which was commissioned by the Orange Shire Council in July 2015.

[2] Robert Bartlett, *First Gold. Ophir NSW*, the author, Orange, 1999; Robin McLachlan and Michael Pearson, *Ophir Reserve Heritage Study and Management Recommendations, report for Cabonne Council, 30 September 1997*, the authors, Bathurst, 1997.

[3] McGowan and Mott, *A Thematic history of the Chinese People in the Orange City, Blayney and Cabonne Shire Councils*, Gwenda Stanbridge, *Chinese in Blayney Shire*, Blayney Shire Local and Family History Group Inc., 2015; G. Stanbridge, *Chinese in Blayney Shire, Part 2*, Blayney Shire Local and Family History Group Inc., 2015; G. Stanbridge, *Chinese in Blayney Shire, Part 3*, Blayney Shire Local and Family History Group Inc., undated; *Bathurst Free Press and Mining Journal*, *Sydney Mail*, *Sydney Empire* and *Sydney Morning Herald*, 1857-1863.

[4] McGowan and Mott, *A Thematic history of the Chinese People in the Orange City. Blayney and Cabonne Shire Councils.*

[5] McGowan and Mott, *A Thematic history of the Chinese People in the Orange City, Blayney and Cabonne Shire Councils;* Stanbridge, *Chinese in Blayney Shire*,; *Chinese in Blayney Shire, Part 2*; *Chinese in Blayney Shire, Part 3*

[6] Stanbridge, *Chinese in Blayney Shire*; *Chinese in Blayney Shire, Part 2*; *Chinese in Blayney Shire, Part 3*; E.C. Allen, *Old Eugowra*, the author, Sydney, 1940; Charles White, *History of Australian Bushranging*, Vol.1, Lloyd O'Neil Pty Ltd, Melbourne, 1981.

[7] G. Stanbridge, *Chinese in Blayney Shire*; *Chinese in Blayney Shire, Part 2*; *Chinese in Blayney Shire, Part 3; Bathurst Free Press and Mining Journal*, *Sydney Mail*, *Sydney Empire* and *Sydney Morning Herald*, 1857-1863; McGowan and Mott, *A Thematic history of the Chinese People in the Orange City. Blayney and Cabonne Shire Councils.*

The Great Cobar explosion

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The Cobar mines have had their share of accidental explosions, misfires, underground fires and spontaneous combustions. The most spectacular and fortunately one of the least injurious was the Great Cobar explosion that occurred at around 7 pm on Saturday 25th January 1908, when the powder magazine of the Great Cobar copper mine, containing 1,750 lbs (795 kg) of explosives, erupted in an explosion that was heard 35km away. A report in the Cobar Herald the following Tuesday gave a detailed and entertaining account of the tumultuous event.[1]

The first indication of a potential explosion came when the son of the mine surface boss, young Horan, observed some smoke and said to his father ‘Hey, dad, the powder magazine’s on fire.’ Mr Horan looked out and could see no smoke, but nevertheless, erring on the side of caution, raised the alarm. The police were alerted and proceeded to the scene, making arrangements to stop traffic on the nearby road. Two local boys, Curly Rankin and Percy Clifton, were sent to warn travellers at the Wrightville end of the road. The police then tried to find Mr. Dart, officer in charge of the magazine, to ascertain the amount of explosives stored there, but were only able to locate Mr. Woolcock, the Underground Manager. Even though they had doubts, as no smoke could be seen, when Mr. Woolcock approached within 50 m of the magazine there was a small explosion or collapse and his doubts immediately vanished. Instantly he retreated, advising the police to move everyone back. He warned ‘there's another heap bigger than that one to come yet.’ As the police were only 200 m away, they doubled their distance from the burning magazine. Then the dome of the magazine collapsed and a surrounding 1 m thick wall was blown down. Twelve minutes later the end came. It was reported that ‘there appeared to be a rent in the top of the dome, through which flames leaped forth and all that was left was heaved skyward with enormous force. In that final explosion, there was an enormous upheaval of flame, sending a shower of stones and a dust cloud to 500 feet.’ Numerous windows were broken and the lights in a nearby pub were extinguished. Amazingly there were only three relatively minor injuries. Curly Rankin, 400 m away on the Wrightville road was struck on the side of the head by a piece of rock and rendered temporarily unconscious, while Percy Clifton was also knocked down by the concussion. At the Cobar end, a young man named Cornish was injured when a rock struck him on the back of the head and another destroyed the front wheel of his bicycle. Given the force of the final blast it was amazing that no one was killed. This was attributed to the police and Mr Woolcock for ‘the timely warning which they gave on a little more than a half hours notice.’

A coroner’s inquest held a week after the explosion concluded that ‘no blame was attachable to anyone’ and that the cause of the initial fire was probably spontaneous combustion or lightning.[2] The Coroner recommended that: the site of explosive magazines in the district should be subject to approval by the municipal councils of Cobar and Wrightville; the buildings should be approved by the Government authorities; and ventilation be improved to keep the inside of magazines in the western districts cool in the summer months. Shortly after, the Great Cobar mine built three new wooden and iron magazines, presumably to reduce the volume of explosives stored in each.

[1] ‘Greatest local explosion on record’, *Cobar Herald*, 28 January 1908, p. 2.
[2] ‘The Cobar explosion – Coroner’s recommendations’, *Sydney Morning Herald*, 3 February 1908, p. 8.

Mining the Cobar Mineral Field: An historical overview

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Cobar has a mining history that extends from the initial discovery and use of ochre by aboriginal people to the present, with almost continuous metal mining over the past 145 years. Although there was early gold prospecting, the main impetus to mineral exploration and development was the discovery of copper in September 1870. Early copper mining was followed by gold and later silver-lead-zinc production, reflecting the polymetallic nature of this major mineral field. Many of the early copper discoveries were made by pastoral workers, who observed the distinctively coloured secondary copper minerals in outcrops.

The Cobar Mineral Field has a total metal endowment exceeding 2Mt copper, 198t gold, 2.7Mt lead, 4.5Mt zinc and 6277t silver. Mining has occurred over four major periods:

- 1870-1921, a period of major copper and later gold mining dominated by the Great Cobar mine;
- 1930-1952, a period marked by the re-emergence of gold mining, focussed on the New Occidental and Cobar gold mines;
- 1961-1985, a period of major base-metal mining following new discoveries, particularly at the CSA and Elura mines;
- 1985 to present, a renaissance in gold mining, continued base-metal mining, new discoveries and re-developments following extensive exploration.

Mining during these periods was controlled or shaped by five key factors: fluctuating metal prices; availability of water; access to fuel; the cost of transport; and technological advances.[1]

Due to its long mining history, the Cobar field encapsulates most phases and developments in Australian mining, excepting the alluvial gold rushes. During early copper mining, handpicked, high-grade ore was transported to South Australia for treatment. Reverberatory furnaces were then built on-site to successfully smelt near-surface ores until the deeper ‘sulphides’ were reached and local supplies of wood fuel depleted. The introduction of water jacket blast furnaces was a ‘game changer’, revitalising the industry, not only in Cobar but throughout Australia, allowing low-grade sulphide ore to be economically treated with reduced fuel requirements.

Gold was identified early in the Cobar ores, but it was not until 1887 following a decline in the copper price and copper mining, that attention was focused on the gold (and silver) potential of the Cobar field. This new impetus led to discoveries throughout the region, including at Mount Drysdale, Mount Boppy and Gilgunnia. Gold also ‘saved the field’ during the Great Depression of the 1930s and into the 1950s, but then declined with the fixed gold price until a renaissance in the 1980s. In this latter period new technology revolutionised gold recovery and the first Carbon in Pulp extraction plant built in Australia was pioneered at the Mount Boppy mine.

Following World War II, interest again turned to base metals, including copper and lead-zinc, with new discoveries and extensions to known deposits delineated by modern exploration methods and deep drilling. This interest, as well as ongoing gold mining, has continued through a number of mining booms and busts. New mining and processing methods have been pioneered or adopted across the Cobar Mineral Field to allow continued economic extraction of its metals.

[1] References relevant to this article are listed in K.G. McQueen, 2016. Mining history of the Cobar-Lake Cargelligo Region 1:500 000 Scale Metallogenic Map, Geological Survey of New South Wales, Maitland, NSW, Australia.

Cobar and the Cornish

Philip Payton

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For much of the nineteenth century, Cornwall led the world in deep, hard-rock mining. Cornish miners and Cornish technology were in constant demand as the international mining frontier developed during the century. For a variety of reasons, not least the demand for Cornish know-how, emigration became a major feature of Cornish life, some 250,000 people leaving Cornwall for overseas destinations during the period 1815-1914.[1] Many of these Cornish emigrants – the 'Cousin Jacks and Cousin Jennys' – made their way to Australia, and from the first were at the heart of its copper mining industry.[2] By the time copper was discovered at Cobar in 1870, there was a large reservoir of Cornish expertise in Australia from which the industry could draw.

Early identification of Cobar's copper deposits, so the story goes, was made by Sidwell Kruge (*nee* Woolcock), a former bal-maiden (female mine worker) from Cornwall, 'an old Cornish "jenny"' as the *Sydney Mail* described her in February 1894.[3] Likewise, the Cornish were engaged to open up the mines, an early arrival being Captain John Varcoe, identifiable by his Cornish name. He was followed shortly by Captain Thomas Lean, born at Bere Alston in Devon of Cornish stock, who arrived from Moonta with six Cornish miners, among them his son Thomas Lean, together with Edward Tonkin, Peter Andrewartha, Thomas Prisk and Thomas Rogers – again, each one identified by his Cornish surname.[4] Among the mines opened was the Cornishman, Scotsman and Australian (sometimes rendered as Cornish, Scottish and Australian, and known generally as the 'CSA'), named in honour of its proprietors: Henry and Richard Nancarrow, George Gibb and John Connelly. In time, the early Cornish settlers were joined by many others, from places as diverse as Redruth, Illogan, Hayle and Helston in the west to St Cleer and Linkinhorne in the east and Tremaine in North Cornwall, as ever their surnames a clue to their Cornish origins: Dunstan, Gluyas. Gummow, Opie, Skewes, Trevena, Uren, and so on. Together, the Cornish played a prominent role in the economic, social and cultural life of Cobar. Overwhelmingly Methodist, they tended to marry within their denominational groups – Wesleyans, Bible Christians, Primitive Methodists – reinforcing their sense of ethnic exclusivity and cultivating an ethno-religious as well as ethno-occupational identity. Many clustered in the adjoining settlement of Cornishtown, named apparently after one Henry J. Cornish.

Although the Cornish adapted readily to the Australian environment, with which many had been familiar for many years, links with Cornwall remained. Edgar Rule, for example, who was born in Cobar and later wrote the First World War memoir *Jacka's Mob*, maintained a correspondence with his aunt in Camborne, Cornwall, and visited her when on leave from the AIF on the Western Front. In this way, Cobar remembered its place in the Cornish transnational world.

This lecture, then, sketches the Cornish impact in Cobar and environs, from the early days of copper mining in the 1870s until the Great War of 1914-18, a period of almost half a century in which they were a visible and significant part of the local community.

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[1] Philip Payton, *The Cornish Overseas: A History of Cornwall's Great Emigration*, Cornwall Editions, Fowey, 2005; reprinted, University of Exeter Press, Exeter, 2015.
[2] Philip Payton, *Making Moonta: The Invention of Australia's Little Cornwall*, University of Exeter Press, Exeter, 2007.
[3] *Sydney Mail*, 24 February 1894.
[4] Patricia Lay, *One and All: The Cornish in New South Wales*, Heritage 2000 Plus, Queanbeyan, 1998, p. 83.

Ye'll naa git me doon in ya pit

Danny Spooner

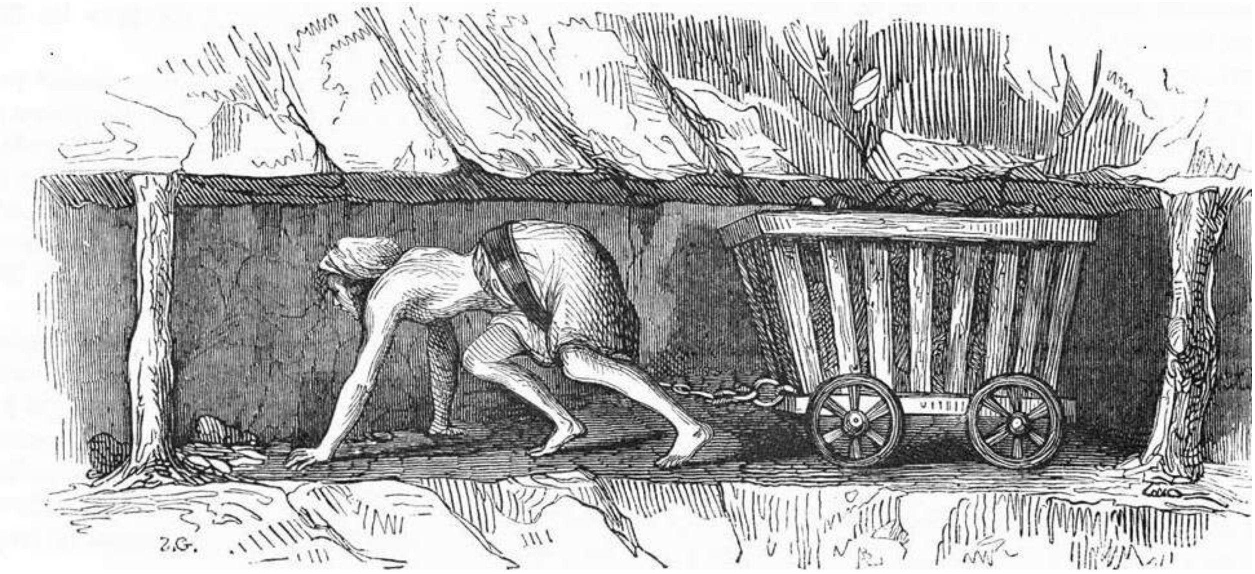
Social Historian and Folksinger, 25 Stanbridge Street, Daylesford, VIC, 3460, Australia

Jowl, jowl and listen lads ye'll hear the coal face wor-kin'
Theors mony a marra missin' lads becos 'e wadden listen lads.
(Durham miner's rhyme)

It is often said that there are two types of history: one which focuses on famous personages, those of consequence, and the other which is made by, and for, the ordinary people. This presentation will focus on the latter, drawing on traditional and contemporary folk-songs to illustrate and remind us that mining was, and can still be, one of the most dangerous occupations on the planet.

Not an academic paper this will be an illustration of some of the realities of coalmining during Britain's Industrial Revolution when, prior to the report of the 1842 Commission into Child Labour, it had been the practice to use boys as young as five and six, and women and girls as young as 8 years old to work underground for ten to twelve hours a day. This was largely because they could be paid less than men. The report was often ridiculed by mine owners who suggested that the children giving evidence were simply scheming liars.[1]

Figure 1: Girl working in a coalmine hauling a tub of coal in 1842. Women and children were employed because they could be paid less, could work in small spaces and needed less air than pit ponies.



Source: Victorian Britain: Children in coal mines, BBC.co.uk.

[1] John Burnett, *Useful Toil,* Penguin Books, Middlesex, England 1977; Dave Douglass, *Pit Talk in County Durham,* TRUEXpress Oxford 1973; Frederick Engels, *The Condition of the Working Class in England,* Granada 1972Roy Palmer, ed, *Poverty Knock,* CUP 1974; Patricia Hollis, ed., *Class and Conflict in Nineteenth-Century England 1815-1850,* Routledge & Kegan Paul, 1973; Roy Palmer, ed, *A Touch on the Time,* Penguin Education, 1974; Raphael Samuel, ed, *Miners, Quarrymen and Saltworkers,* Routledge & Kegan Paul, 1977; John Stevenson, *Popular Disturbances in England 1700-1870,* Longman, 1979; E.P. Thompson, *The Making of the English Working Class,* Victor Gollancz Ltd, 1964.

Chillagoe to Cairns via Sunnymount: Still Oertling on

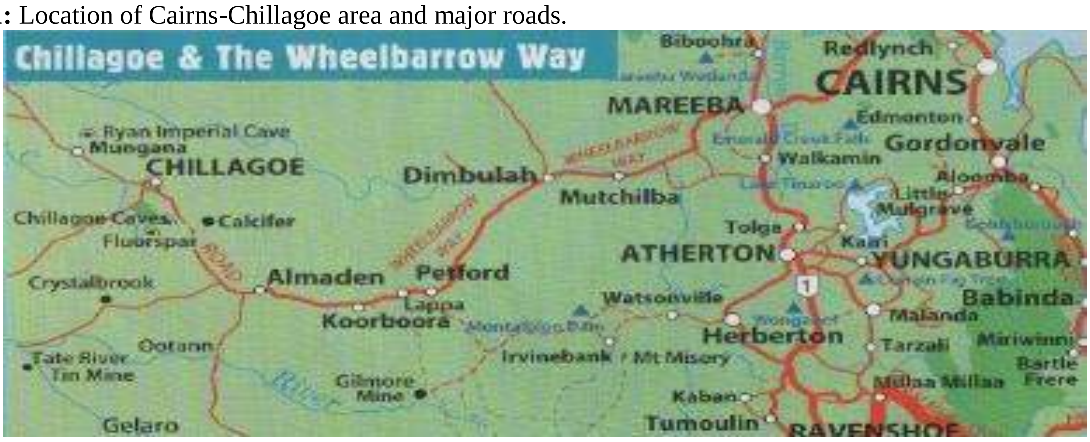
Nicola H. Williams[1] and Ruth S. Kerr[2]

[1]Retired Chemistry Academic, Monash University, Victoria, 3800
[2]Adjunct Professor in History, School of Historical & Philosophical Enquiry, University of Queensland, Qld, 4072

In 1874, James Venture Mulligan was sent out by Scottish mining entrepreneur John Moffat to prospect for copper in the Chillagoe area (Fig. 1). He was initially unsuccessful, but in 1883 found traces of copper. In 1894 Moffat built the first copper smelter on the Chillagoe field at Calcifer, 10km east of William Atherton's *Chillagoe* Station. Moffat promoted the construction of the Mareeba to Chillagoe railway in 1897 for more efficient transport, one result being that the Chillagoe smelters opened in 1901 while those at Calcifer closed in 1903. The smelters were intended to service the company and other local mines, the main sources being cuprite from the Calcifer, Chillagoe and Mungana mines. However, there were severe problems, the worst being that the mineral deposits were shallow and scattered, and a main lode was never found. In spite of company reconstructions, technical improvements, and even after government takeover, the smelters finally closed in 1943. Between 1901 and 1943, the Chillagoe smelters treated 1.25Mt of ore, to yield 60,000t copper, 50,000t lead, 181t silver, and 5t gold. There was a fire-sale in 1949, most of the material being bought by the Mareeba mining agent Harry Thompson. Artefacts included two assay balances from the assay lab, and it was Henry Bird, from a tin mining family, who later bought the balances, one of which was an Oertling.

In 1880, lode tin mining had commenced in the Herberton area, and Moffat pioneered the investment, including building a very efficient mill and smelter at Irvinebank, in 1884. Many smaller operators followed, across the Walsh and Tinaroo tin fields, one of whom was Tommy Burns. The company, of which Moffat was a shareholder, erected a five head stamp battery at Sunnymount, just south of Lappa Junction, which operated from 1908 to 1911, when the tin lode was lost. However, it was quite a rich mine, producing ~1100t of tin over this period. Henry Bird's father Harry rebuilt the battery, with 10 stamps and four concentrating tables, completing the job in ~1954. Henry joined his father and brother John there in 1957, when they all, with another brother, Kevin, built a new battery, the 'Prince Alfred', at Sunnymount. It was on this site that Henry set up an assay office, in which he used the two balances which had come from Chillagoe. During her Oral Mining History project, Ruth Kerr discovered that Henry, now retired to Cairns, owned an Oertling, an interesting addition to the Oertling dispersion story.[1]

Figure 1: Location of Cairns-Chillagoe area and major roads.



[1] General Source Authors: Peter Bell, Geoffrey Blainey, Kett Kennedy, Ruth Kerr, Ian Plimer. Queensland Government Tourist website. Personal communication from Henry Bird.

Notes

Field Trip Program

Field Trip Schedule

Day	Times	Field Trip
Monday	1.30-5.30 pm	Fort Bourke Hill - New Cobar open pit. Group then splits to visit the CSA gossan and mill **or** the Peak Gold mine operations. Groups combine to finish at Old Peak historic site.
Tuesday	8.30-10.30 am	Inspection of Great Cobar site and museum. Great Cobar Heritage Centre.
	1.30-5.30 pm	Mt Boppy - Canbelego.
Thursday	8.30 am-1.30 pm	Choice of Mt Grenfell aboriginal paintings **or** McKinnons Tank gold mine (packed lunch provided).
Friday	7.30 am-6.00 pm	Nymagee-Hera **(Optional)**. At Hera the party will be split into two groups to assist with logistics (packed lunch provided).

Permission and assistance to visit these sits from the relevant mining companies and land owners is gratefully acknowledged.

Important Safety Information

The field sites visited as part of the conference will include stops on roads, at historic mine sites and on currently active mine sites and treatment plants. **Please take the appropriate precautions for your personal safety and the safety of others at all sites.**

At road stops be aware of traffic. The roads may seem quiet but periodically there can be sudden heavy traffic including large trucks.

On mine sites you will be required to wear the designated personal protective equipment (PPE). This will include: steel capped boots, hard hat, high vis vest, and safety glasses. If you have any of these items please bring them with you as supplies on site are limited. You will also be required to wear a long sleeve shirt and long trousers.

At active mine sites follow the instructions of your company guide at all times. Do not approach too closely (<2m) the edge of open cut mines as these may be unstable and collapse. Do not approach too closely rock faces above you that may be unstable. At old mine sites be aware of the likely presence of hidden, open shafts or other obscured hazards such as discarded equipment.

For all field activities you will need to bring stout footwear and suitable clothing (including a hat).

As October is in mid-spring, be aware of the possible presence and activity of snakes. The weather may also be hot, so please make sure you have adequate sun protection and drink plenty of water to stay hydrated.

Site Locations

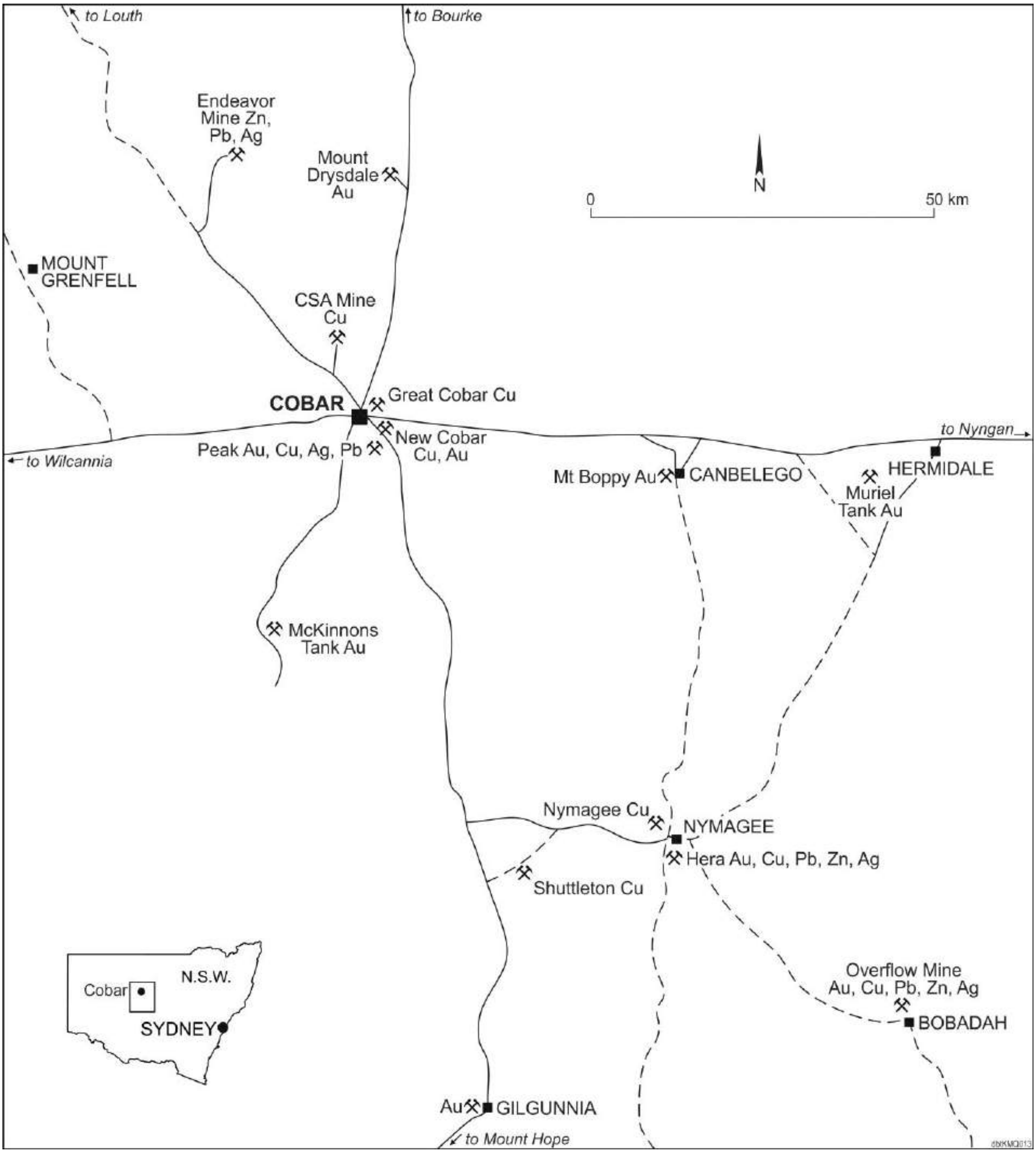


Figure 1: Map of the Cobar region showing the location of some mining sites.

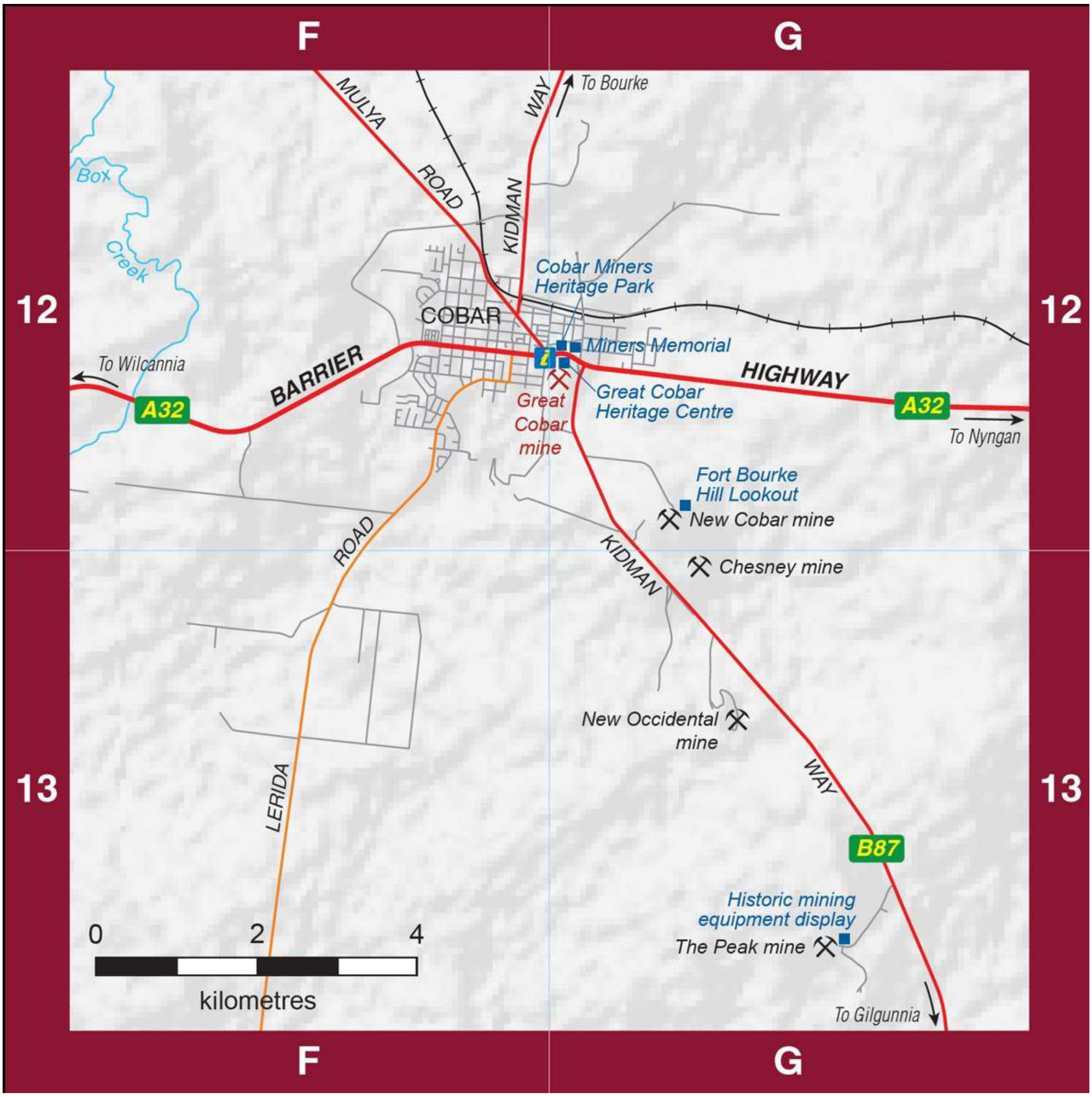


Figure 2: Some mine site locations close to Cobar.

Recommended treatment for snake bite (from St John Ambulance, Australia):

- Reassure patient and ask them not to move. Note time of bite.
- Apply broad crepe bandage over bite site.
- Apply pressure bandage, starting just above the toes or fingers of the bitten limb and wrap upwards as far as possible, including the bite site. Apply firmly without stopping blood supply.
- Immobilise the bandaged limb.
- Keep patient still and get them to a hospital as soon as possible.
- Regularly check circulation in fingers and toes. Manage for shock.

Site Descriptions

K.G. McQueen

Cobar Discovery and Development of the Great Cobar Copper Mine

In September 1870 copper was discovered at 'Kubbur', an aboriginal mining site and water hole in remote country between the Darling and Lachlan Rivers. Three contract well sinkers, Charles Campbell (Danish name Ferdinand Kempf), Thomas Hartman (Danish name Jens Hartmann) and George Gibb had been led to the site by their aboriginal guides Frank and Boney, while travelling south from Louth on the Darling River to Gilgunnia.[1] Aboriginal people had mined ceremonial pigments of ochre, kaolin and the blue and green copper minerals at 'Kubbur' for generations.[2] The party camped at the water hole and noticed the blue and green staining on its walls. In the early 1860s the three contractors had tried their luck on the Victorian goldfields and were sufficiently curious to collect samples of the brightly coloured mineralisation from a nearby outcrop.[3] The next day as they continued south they met Henry and Sidwell Kruge and showed them the specimens. Sidwell (*nee* Woolcock) had worked as a 'bal girl' in the Cornish copper mines and immediately identified the samples as copper ore. [4] Campbell, Hartman and Gibb returned to Bourke, and on the 6th of October 1870 in partnership with local businessman Joseph Becker, they took out a 40 acre mineral conditional purchase claim.[5] A three ton sample was sent to Louth by bullock dray and then to Adelaide by river boat for testing. Assays received in February 1871 showed 33% copper.

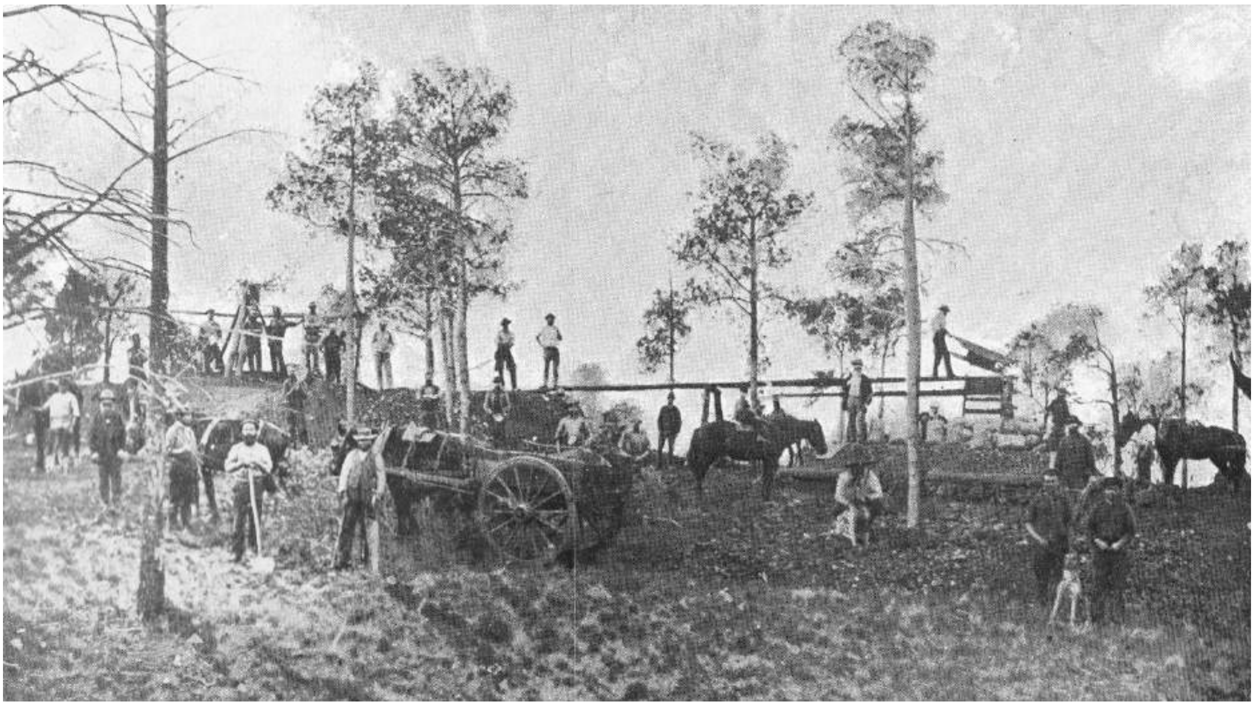


Figure 3: The Cobar copper mine in 1874. Source: J.E. Carne (1908)[6], photo from Frank Lean.

For four months from May 1871, the Cobar mine was worked by John Varcoe and four miners for 250t of ore, 50t of which were sent to Adelaide for further testing. The results were good, clearly establishing the value of the deposit and leading, in late 1871, to formation of the Cobar Mining Company with 200 shares issued at £10 per share.[7] The initial owners were the three well sinkers and four leading men of Bourke, Joseph Becker, William Bradley, Russell Barton and

James Smith. Captain Thomas Lean, an experienced mine manager, was appointed to supervise mining and arrived at Cobar with six Cornish miners on the 4th November 1871.[8] The following year the Cobar Copper Mining Company Ltd was registered with 74 shareholders and nominal capital of £20 000.[9] Hartman and Campbell sold their shares to Joseph Becker, but Gibb, Smith and Barton retained shares, while Bradley and Becker became major shareholders.[10] About 3000t of high grade ore were transported by teams to Bourke and then by river steamer to the Port Adelaide Smelting Works. It was clear that it would be more profitable to smelt the ore on site, but progress was delayed by a severe drought in 1873 and lack of sufficient water for brick-making. In 1875 the first two reverberatory furnaces were constructed followed by another four in 1876, allowing lower grade ore and heaps of 'seconds' from the earlier mining to be treated on site.[11] In January 1876 the Cobar Mining Company amalgamated with the adjacent Southern Cobar Copper-mining Company to form the Great Cobar Copper Mining Company (Ltd).[12] The merger resulted in greatly increased production and by 1881 the new company had 14 furnaces.

The Great Cobar Company operated successfully until 1887 when it began to falter due to low copper prices, shortage of firewood for the smelters and high transport costs, including for a trial shipment of Dubbo coal to substitute for firewood. The miners and wood carters were stood down and only the smelters continued to operate. All operations ceased in 1889 when the company was caught up in the failure of the Société des Métaux, who had attempted to corner the international copper market and artificially drive up the price.[13] Closure of the mine was a stunning blow to Cobar with many families leaving town.[14] For some time the mines and residents of Cobar had lobbied the New South Wales Government for a connection to the expanding railway network and finally in 1892 the railway reached Cobar. This would greatly benefit mining by reducing transport costs.

In 1893 the Cobar mine was let on tribute to the Great Cobar Copper Mining Syndicate, a group of entrepreneurs with interests in the Rix's Creek coal deposits near Singleton. They planned to take advantage of the new railway connection to cheaply bring coke to Cobar to operate new water jacket blast furnaces and transport copper matte to Lithgow, where they eventually built a large refining plant with roasting furnaces and an electrolytic refinery. The introduction of water jacket furnaces allowed a dramatic increase in copper production from ore with an average grade of 4% copper. In the first six years of operation twice as much ore was smelted as had been treated in the previous history of the mine. From the profits, the Syndicate progressively purchased shares in the Great Cobar Company, which still held the mine, and in 1900 they purchased the mine for £500 000 receiving back two thirds of the price through their part ownership.[15] From 1902 to 1905 major improvements were made, including introduction of Naismyth slag pots, larger furnaces, and deepening of the workings to 320m. The Cobar-Chesney mine was also purchased and its more siliceous ore blended with that from Great Cobar to improve fluxing.[16]

In 1906 the Syndicate sold their Cobar operation to the Great Cobar Ltd, a company set up by British investors. The new company invested heavily in new equipment including larger furnaces and a converter plant, and sunk a new three compartment shaft to 300m. By 1907, 964 men were employed in the mine and works. The new plant was commissioned in August 1908, but ran into immediate problems with failure of the three large water jacket furnaces. The company acquired other operations in the Cobar area, including the Peak mines and the Cobar Gold Mine, which could provide siliceous ore for blending and allow efficient extraction of contained gold and silver by the copper matte.[17] A major plant refurbishment was completed in 1912 and northern orebody extensions discovered, but the commencement of WW1 and financial difficulties led to closure of the mine in 1914. As the war continued and the copper price skyrocketed operations resumed in 1916, but production never reached pre-closure levels. A sharp fall in the copper price in 1919 and metallurgical difficulties related to a shortage of basic ore for blending led to the final closure of the Great Cobar mine. Associated mines including the Chesney and Cobar Gold mine also closed.

Over its life, the Great Cobar mine produced almost 115 000t of copper, 288 000oz of gold and more than 46 700kg of silver.[18] The most profitable operation was during the time of the Great Cobar Mining Syndicate. The later period of the Great Cobar Ltd was characterised by over-capitalisation and costly mistakes and although the mine brought much wealth to Cobar, the working miners and NSW Railways, profits for the shareholders were slim.[19]

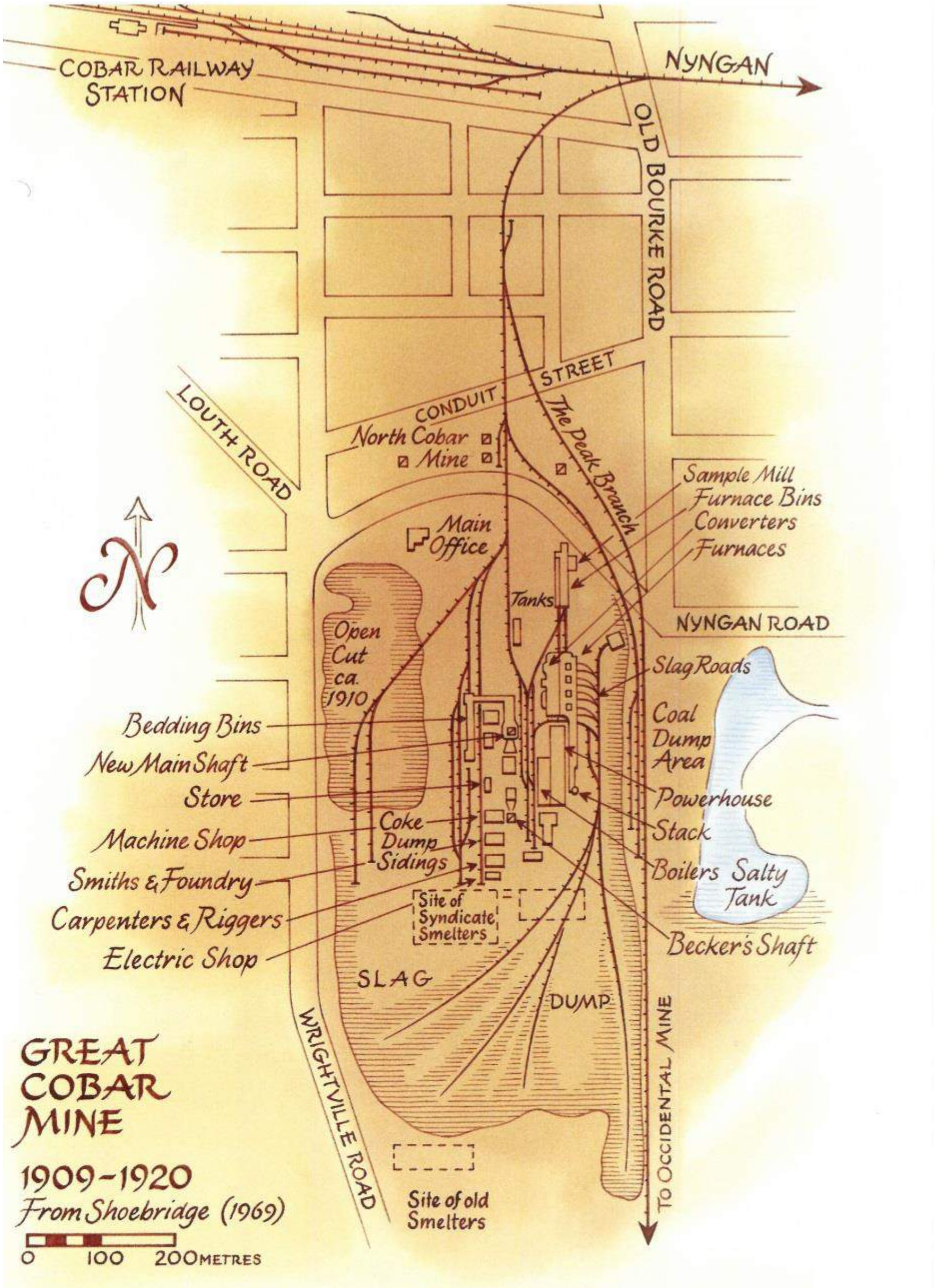


Figure 4: Plan of the surface installations of the Great Cobar Mine following completion of the great expansion in 1909. Plan drawn by Shoebridge (1969), from photographs of the mine.[20]

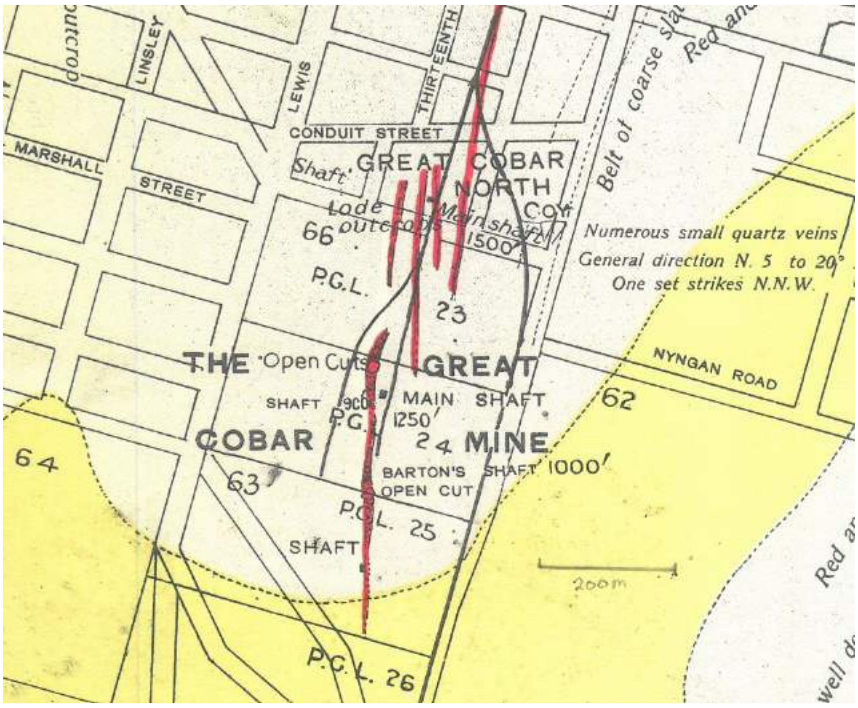


Figure 5: Excerpt of map from E.C. Andrews (1911), showing location of the various Cobar copper lodes and some of the workings of the Great Cobar and Great Cobar North mines.

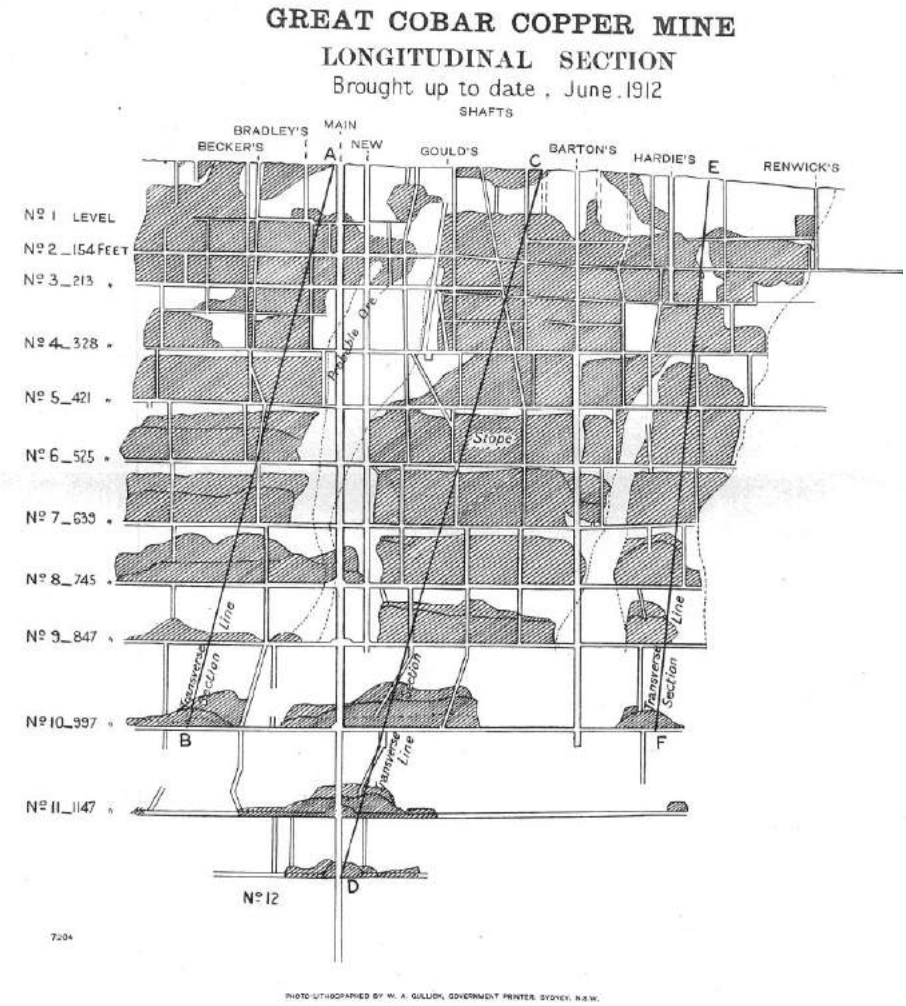


Figure 6: Long section, view to east, of the Great Cobar copper mine in 1912. Shading shows stoped areas. Updated from Andrews (1911).

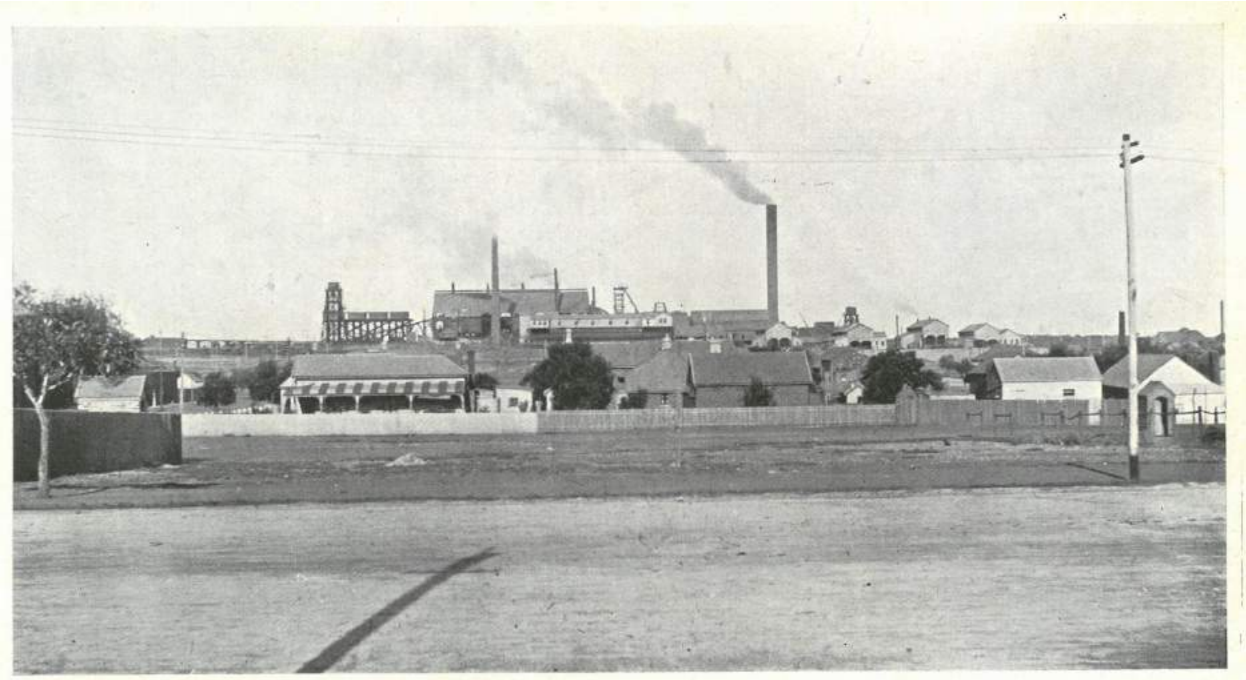


Figure 7: The Great Cobar Copper Mine surface plant in 1911. Source: E.C. Andrews (1911).

Figure 8: Miners working in stope at the 90 fathom level of the Great Cobar Mine ca. 1900. Source: J.E. Carne (1908), *The Copper Mining Industry of New South Wales*.

The Peak Mines

High-grade gold-silver ore was found at The Peak, a prominent hill 10km south of Cobar, by Tom Barrass and John Conley in 1895. The discovery led to a pegging rush and much dispute over titles before a number of mines were developed including the Conqueror-Brown, Blue Lode, Big Lode and Cobar Peak. An interesting aspect of this discovery was that the area had previously been prospected without recognising the rich, near-surface gold developed in blue and brown slate. A small mining centre with a number of crushing plants soon developed. Ore was also sent to the Great Cobar mine for gold recovery by smelting. [21] This small scale activity declined when deeper primary ores were reached and in 1906, Great Cobar Ltd acquired the Peak Mines as a source of siliceous ore. The demise of local copper mining and smelting in 1919 further reduced activity.

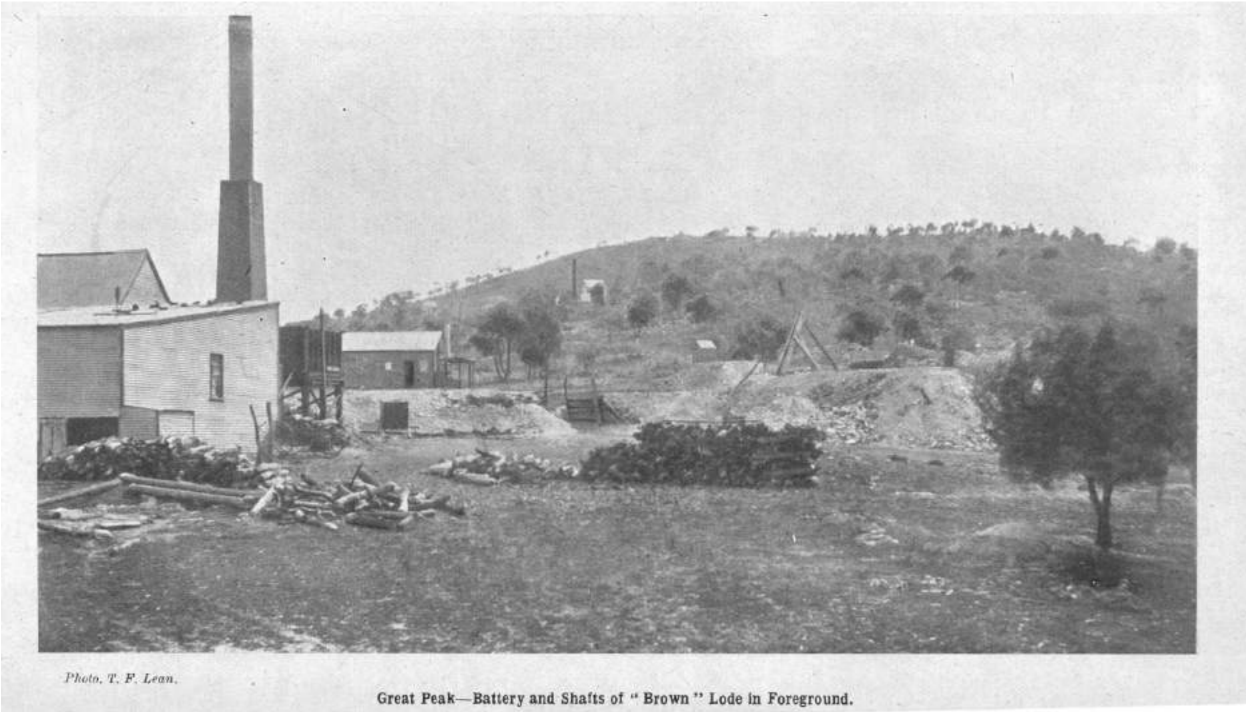


Figure 9: The Great Peak battery and workings on 'Brown' lode. Source: E.C. Andrews

In 1922 Peak Mines NL acquired an interest in the Peak area and mined the Conqueror and Brown lodes until 1940. These leases were taken up by E.K. and C. Freeman in 1942 and the Blue Peak Syndicate secured the Blue Lode area. Both parties worked the lodes intermittently until 1953 for a modest output of gold and silver. Diamond drilling with Commonwealth Government aid in 1942-3 at the Big Lode indicated a broad zone of weak copper-lead-zinc mineralisation, but stopped short of testing the main Peak lodes at depth.[22] Over the next three decades there was a general lack of interest in gold exploration due to the fixed gold price and relatively high mining costs. This changed in 1980 after the price spiked following demonetarisation of gold in 1971. Cobar Mines Pty Ltd and CRA Exploration Pty Ltd initiated an exploration program to assess the gold potential of the Cobar field, particularly the Peak line of lode. The first drill hole to test the down dip extensions of the Big, Brown and Conqueror lodes intersected high-grade gold and base-metal mineralisation at a depth of 300m. From 1982-85 a new Peak orebody was defined by drilling.

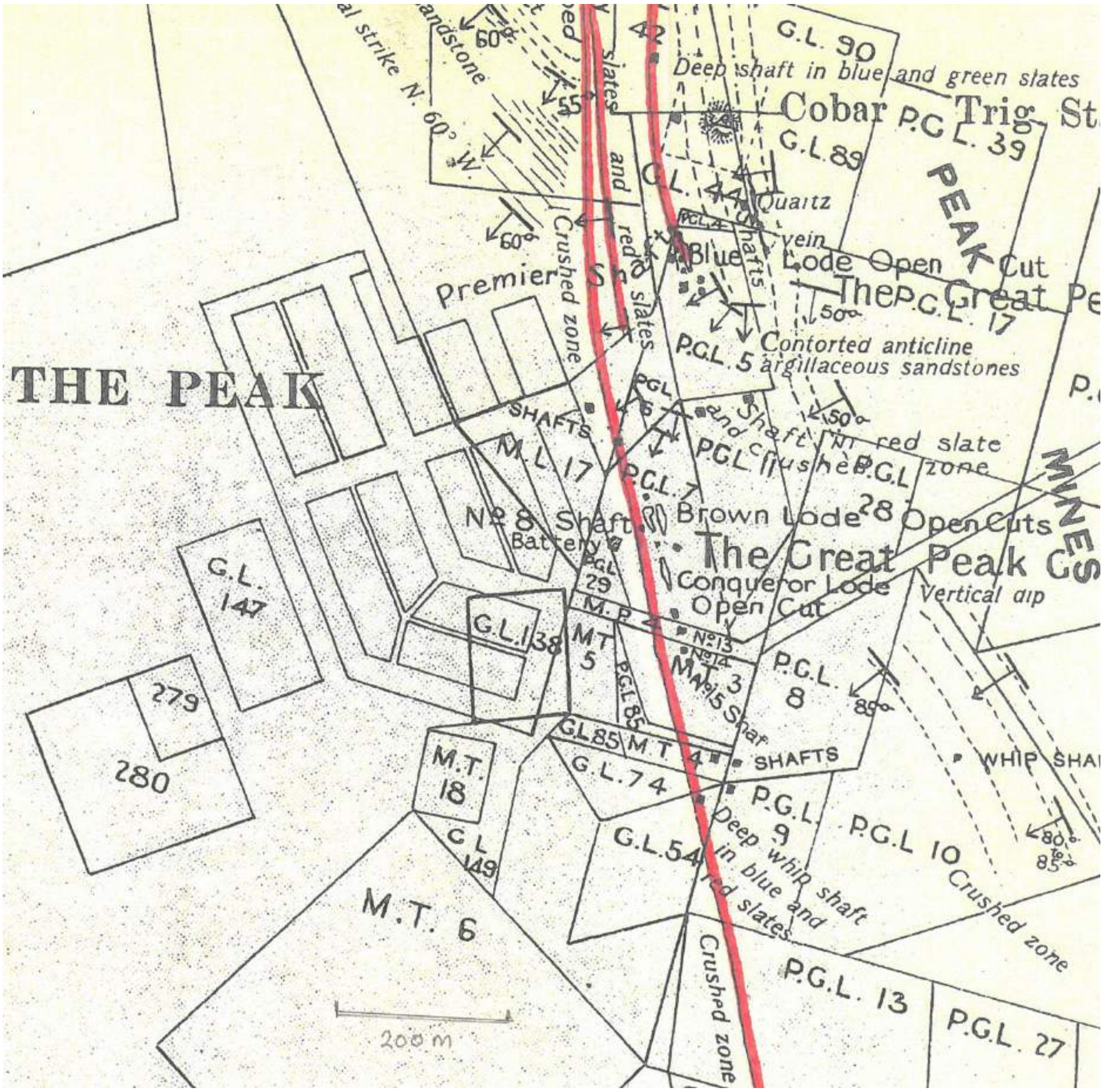


Figure 10: Excerpt of map from E.C. Andrews (1911)[23] showing the mineralised zones (red) and historic mine workings in the Peak area, Cobar Mineral Field.

In 1985 Cobar Mines commenced a 570m deep shaft with cross cuts to facilitate underground drilling and extract a bulk sample for metallurgical testing. Results from a feasibility study were positive and in June 1990 CRA committed to an underground mine based on reserves of 3.9Mt of 7.1g/t gold, 0.8% copper, 1.3% lead, 1.5% Zn and 14g/t silver. CRA formed Peak Gold Mines Pty Ltd to mine the deposit and full production commenced in October 1992.[24] Peak Gold Mines has operated profitably up to the present under several different owners. From 1998 the operation has also mined the deep Perseverance orebodies discovered to the south, as well as redevelopments of the historic New Cobar, New Occidental and Chesney mines. Processing is through a central plant incorporating a gravity circuit and associated intensive leach reactor, a conventional flotation circuit and a cyanide tank leach circuit.

CSA Mine

The CSA mine had an inauspicious beginning as a copper mine, but is now the largest copper producer in the Cobar region. In late 1871, prospector Thomas O'Brien discovered a large gossan on a low rise 11km north of Cobar.[25] He showed the site to George Gibb and John Connelly who decided it was worth claiming and proceeded to Bourke to take out a mineral conditional purchase claim. On arrival the pair realised they had insufficient funds, so approached local businessmen, Henry and Richard Nancarrow to help pay the £20 deposit and become partners.[26] The claim was lodged on the 1st of February 1872 and called the Cornish, Scottish and Australian (CSA) mine after the partners' respective nationalities.[27] A company was formed, but surface prospecting and shaft sinking failed to find payable ore. In fact, there was to be a long and disappointing period of exploration by a number of groups before payable ore was finally located in 1905. This was rich secondary lead-silver ore, the redeposited accumulation from 135m of leaching of the overlying oxidized zone. The discovery sparked a small exploration boom and visiting experts considered the find the biggest lead discovery since Broken Hill.[28] It was not until 1910 that the first signs of economic copper ore were discovered and by this time more than £100 000 had been expended on exploration and development with no return to shareholders.

Figure 11: The C.S.A. mine in 1905, during development by the C.S.A. Development Syndicate. Source: NSW Geological Survey Photo Collection.

The C.S.A. Development Syndicate, set up by George Blakemore, General Manager of the Great Cobar mine, acquired the CSA mine in 1905 and deepened the old main shaft. Blakemore recognized the importance of testing deposits at depth, below the zone of oxidation and leaching. After discovery of the silver-lead ores, C.S.A. Mines Ltd was floated to further develop the mine. A new shaft was commenced to test the deeper sulfide zone and connect with the existing workings to improve access and ventilation. By the end of 1906 the new shaft was down 76m and there had been significant additions to the surface plant, including a new winding engine and steam condenser to conserve water. In 1907 L.J. Winton, an engineering graduate of the University of Sydney, took over management and extended the underground development to discover large bodies of mixed sulfides.[29] Mining continued until April 1909 when the known secondary lead ore was exhausted and the mine was closed.

The CSA re-opened in 1910 and a search made to the east of the underground workings for possible copper lenses beneath gossans east of the main surface gossan. After driving a short distance on the 450 Level a 3m wide copper orebody was found. By the end of 1911 the CSA mine had been developed on four levels down to 200m. Although significant copper-bearing lenses had been found, the largest were highly pyritic admixtures of lead, zinc and copper with a copper grade too low to mine as copper ore. Subsequently, underground diamond drilling intersected three higher grade copper lenses, indicating that the CSA could become a copper mine. Additional rich secondary lead ores were also found and mined up until 1914, when attention was focused on the copper. Up until 1916 all the CSA ores had been sent away for processing and hence the company had concentrated on the rich silver-lead and basic copper ores, which were most in demand. It was realised that larger bodies of lower grade and siliceous copper ore could be processed on site if the railway was extended from Cobar to the mine and a smelter built. This came to fruition in 1917 and smelted matte was railed the Electrolytic Refining and Smelting Company at Port Kembla. In 1918 C.S.A. Mines Ltd built its own refinery at Kandos, which by the end of the year had treated 55 028t of ore and produced 2232t of copper, 60 294 ozs of silver and 558 ozs of gold. Success was short-lived due to the collapsing copper price in 1919 and a disastrous underground fire at the mine in March 1920 which led to its closure.[30]

Following WWII the Australian Government was keen to rehabilitate the mining industry and the Bureau of Mineral Resources, together with the NSW Geological Survey, established a project to reassess the Cobar field. The Broken Hill companies also became interested in exploring the potential of the area. Enterprise Exploration Co. Ltd, a subsidiary of the Zinc Corporation, acquired the derelict CSA mine in 1951, dewatered the workings and commenced underground diamond drilling. Further exploration indicated at least 17Mt of ore containing 1.3% copper, 1.3% lead and 3.2% zinc between 150m and 490m and another 3.6Mt of 3% copper, 1% lead and 3% zinc in a separate lens. However, a feasibility study indicated that this ore could not be extracted economically. In 1960, as part of a joint venture with Broken Hill South Ltd, deeper diamond drilling from the surface revealed ore extending to a depth of almost 1km and a significant new copper zone (Eastern Lode) was discovered east of the known Western Lodes. These and subsequent discoveries ultimately led to development of the modern CSA mine, which commenced production in 1964. At the time, this was the most technologically advanced mine in Australia and its large-scale development brought major benefits to Cobar, including connection to the State electricity grid and a water pipeline from the Bogan River. Subsequent mining and exploration by a number of owners has discovered additional ore systems, particularly copper-rich lenses, down to at least 1.8km. Current mining extends to 1.6km, making the CSA the second deepest mine in Australia. Although in the past the CSA mine has produced significant zinc, lead, silver, copper and some gold, current production is focused on copper and by product silver.[31]

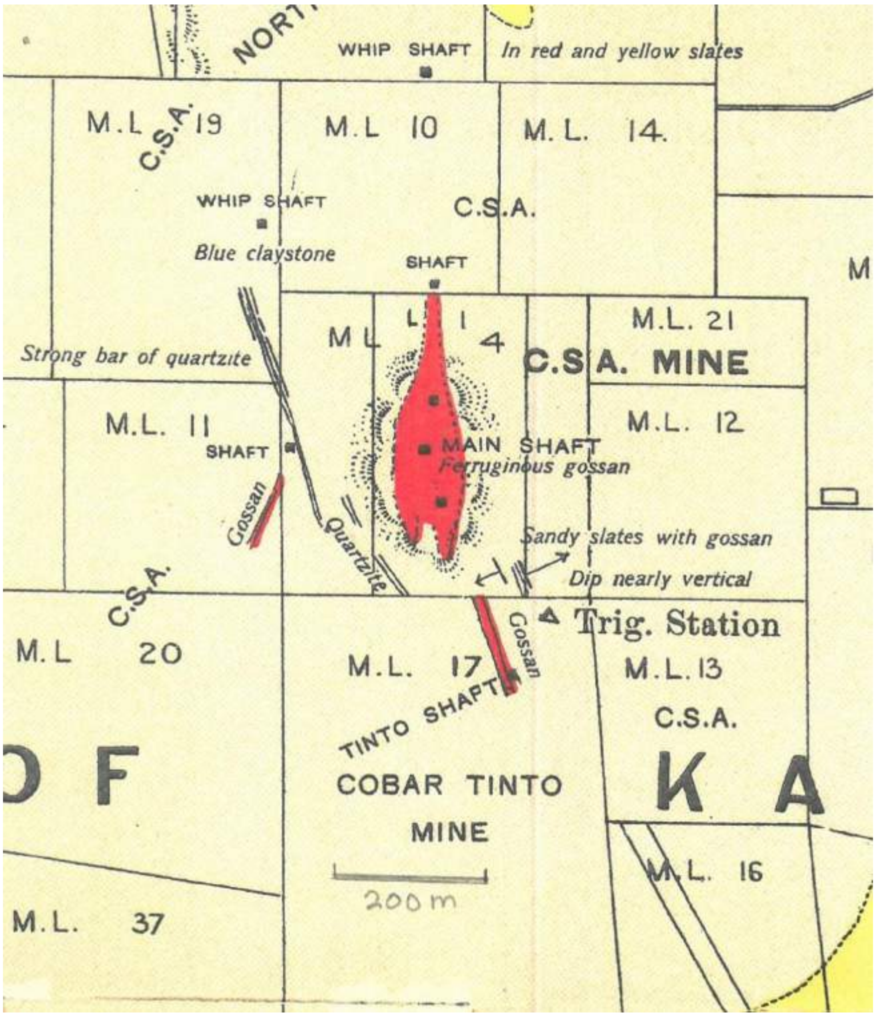
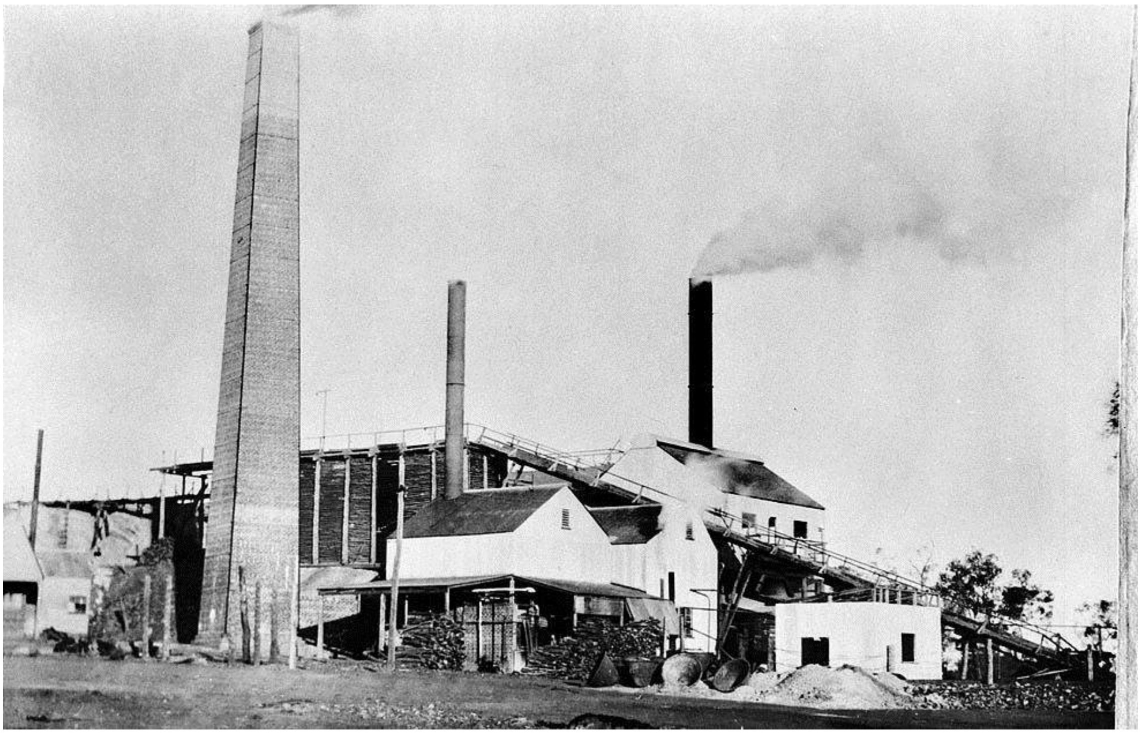


Figure 12: Excerpt of map from E.C. Andrews (1911) showing the large gossan (red) and various shafts at the CSA site in 1911.

Figure 13: The C.S.A. smelting works in 1918. Source: NSW Geological Survey Photo Collection.



Mount Boppy Gold Mine

In 1896 Thomas Reid discovered gold near Mount Boppy when he attempted to trace the source of some unusual quartz blocks containing fine-grained gold. This discovery was not the source, but shortly after, prospecting mate Michael O'Grady found the outcropping source nearby.[32] The partners pegged a gold lease, conducted some preliminary testing and in November 1897 sold their claim to the Anglo-Australian Exploration Company for £800. This company systematically outlined, sampled and proved the deposit before floating the Mount Boppy Gold-Mining Company in England in 1900. Further testing, construction of the mine and erection of a modern crushing and cyanide extraction plant continued until May 1901 when production commenced. In the first seven months 12 400t of ore were crushed and 6092 ozs of gold produced. From 1903 to 1905, mine superintendent George Davey made significant improvements to the mine and plant and by 1905 Mount Boppy was considered the leading gold mine in NSW, contributing £50 000 annually to the State economy. The mine employed 300 men and supported the newly established town of Canbelego with a population of 1500.[33] Underground development had extended to 122m and revealed a lode resembling an inverted saddle reef.[34] Annual gold production continued to increase until it peaked at just over 34 000 ozs in 1908.

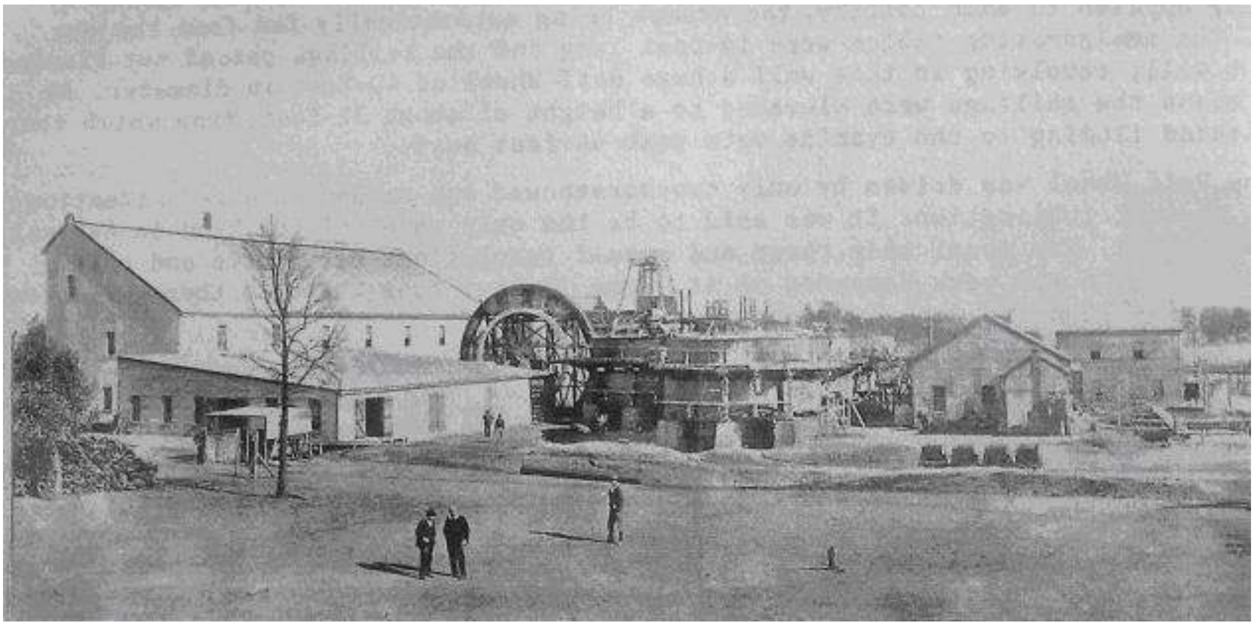


Figure 14: View looking towards the west of the Mount Boppy mine works in 1905.
Source: *Sydney Mail* 13 July 1905.

As deeper sections of the deposit were accessed the proportion of refractory ore increased necessitating changes to the processing plant. Experimentation indicated the advisability of finer grinding and under the direction of superintendent James Negus and metallurgist Bill Williamson an innovative plant, incorporating four tube mills, Dorr thickeners and Moore vacuum filters, was constructed in 2012. Between 1913 and 1915 an extensive development program, including diamond drilling, discovered lode extensions, particularly along the western leg of the deposit. Production continued through to 1916 when operations were severely affected by manpower shortages and high costs related to World War I. The company responded by sinking a new three compartment shaft to allow cheap mining of the previous shaft pillar by open cut methods. Production resumed in 1918 but in November ceased until September the following year due to severe drought conditions and lack of water for the plant. By 1921 gold production was down to 8685 ozs and in 1922 the mine was let to tributers, but closed the following year. In this first phase of mining the Mount Boppy mine had produced 13.5t of gold from about 1Mt of mined ore. By 1911 investors had received a 350% return on their investment and over the 21 year mine life the operation returned five times the original capital cost.

There was minor gold production from remnant ore at Mount Boppy between 1928 and 1941, as well as attempts to re-treat the large volume of tailings. Renewed interest was shown in these gold-bearing tailings from 1963 and in 1973, partly in response to the increased gold price, Leonard Oil was sponsored by Westralian Sands Ltd to assess the tailings, which they now owned. Leighton Mining took an interest in the venture and in 1974 built the first Carbon in Pulp cyanide treatment plant in Australia at the old Mount Boppy mine to apply this revolutionary technology to treating the tailings. Between 1975 and 1976 this venture produced 5394 ozs of gold and 4462 ozs of silver from 200 000t of tailings but was not financial success. However, from 1995 to 2006 Polymetals Australia Pty Ltd successfully recommenced operations with a modified plant processing additional tailings and remnant ore from an open pit into the old underground workings containing tailings as back fill. In recent years there has also been renewed exploration around the deposit.[35]

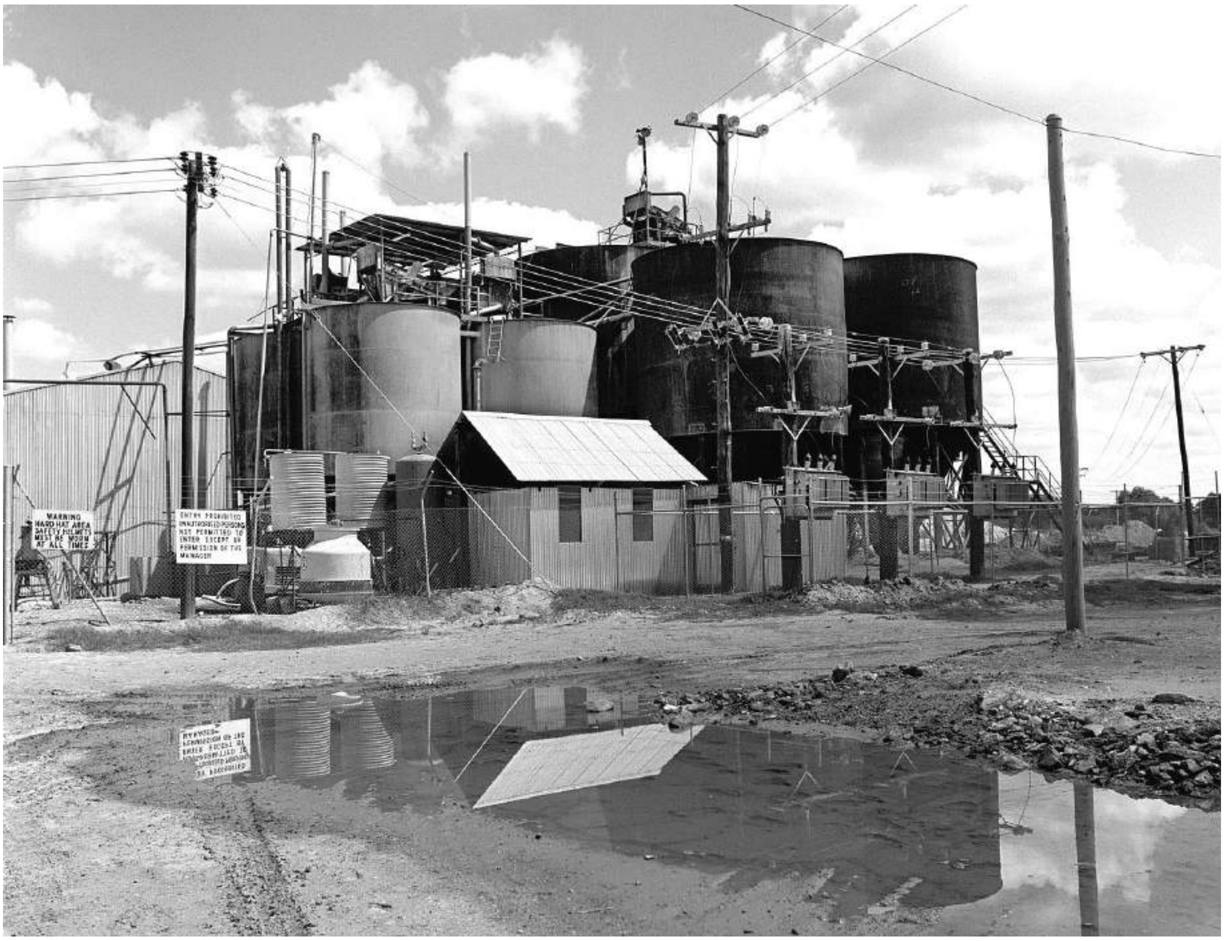


Figure 15: The first cyanide CIP plant built in Australia, at Mount Boppy, by Leighton Mining NL in 1974. Source: NSW Geological Survey Photo Collection, photograph taken by G. Hicks.

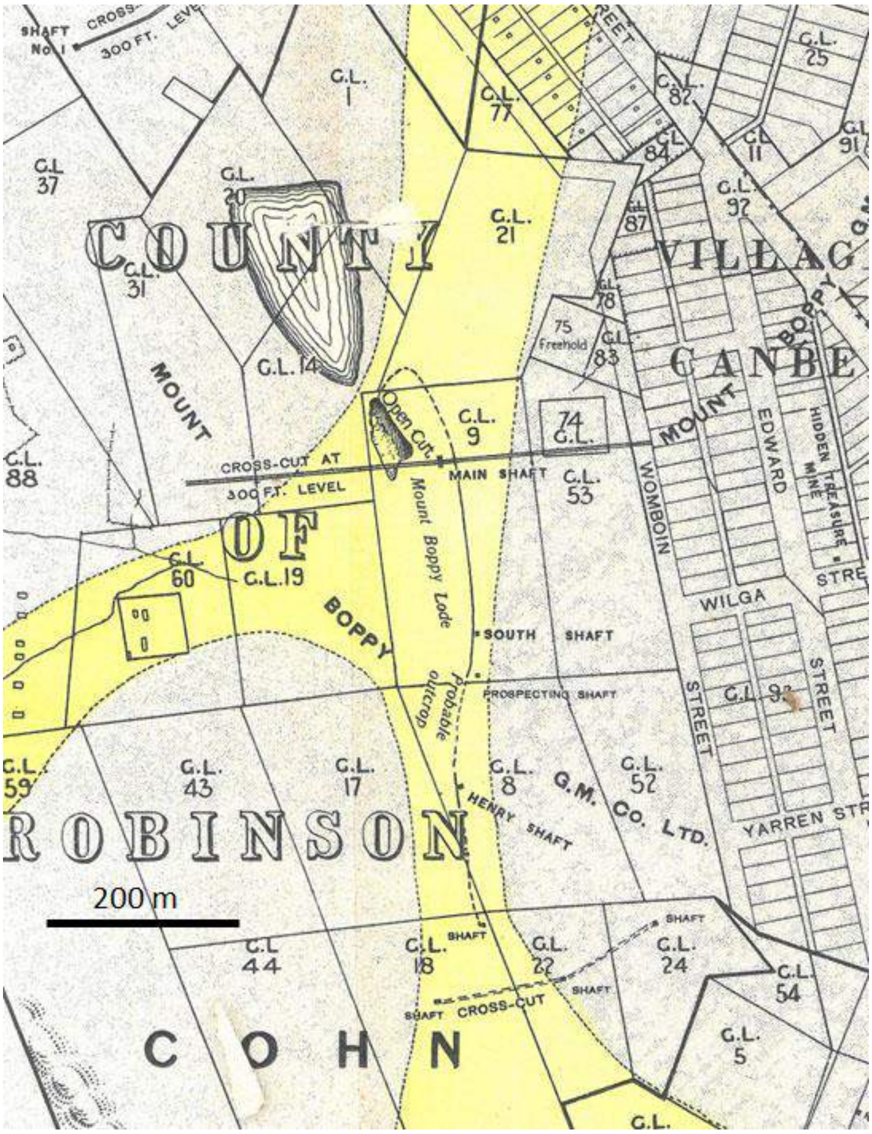


Figure 16: Excerpt of map from E.C. Andrews (1915) showing location of the Mount Boppy gold mine east of the township of Canbelego.

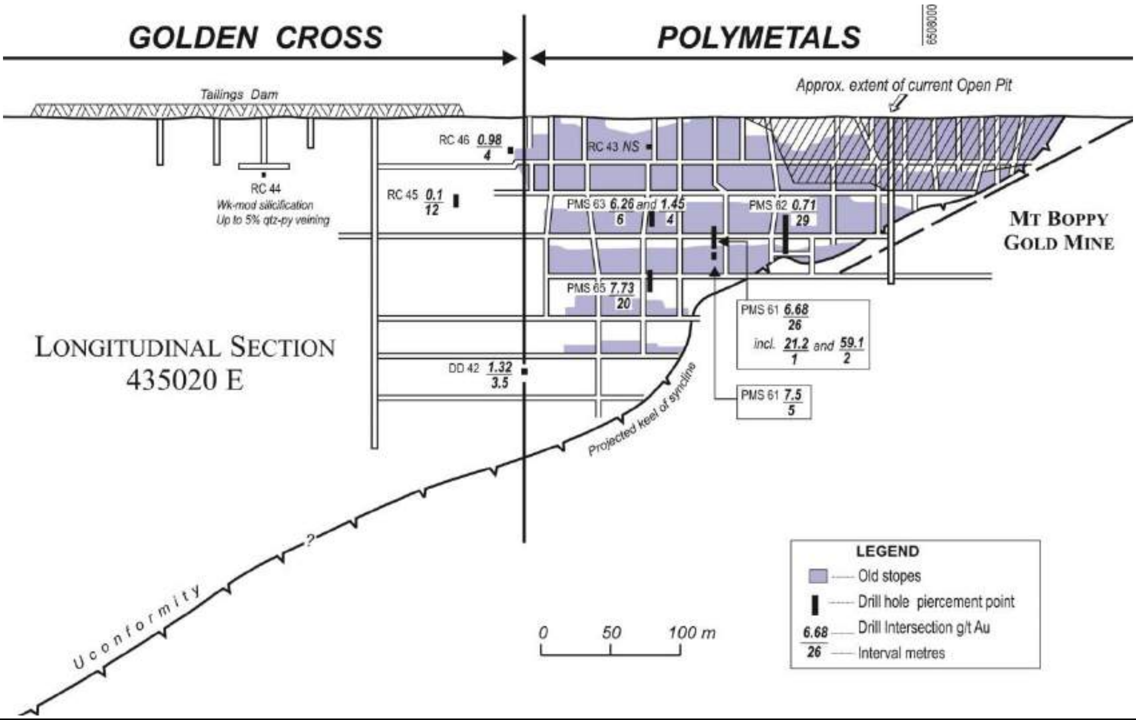


Figure 17: Long section (north at right) of the Mount Boppy gold mine showing old workings, stopes and the new open pit in 2003. Source: Golden Cross Resources Ltd, ASX Ann. 2/12/2003.

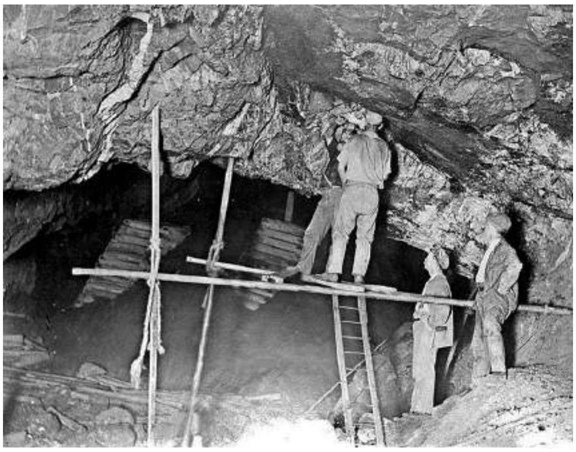


Figure 18: Stopes on the No. 3 Level Mount Boppy mine, 1905.

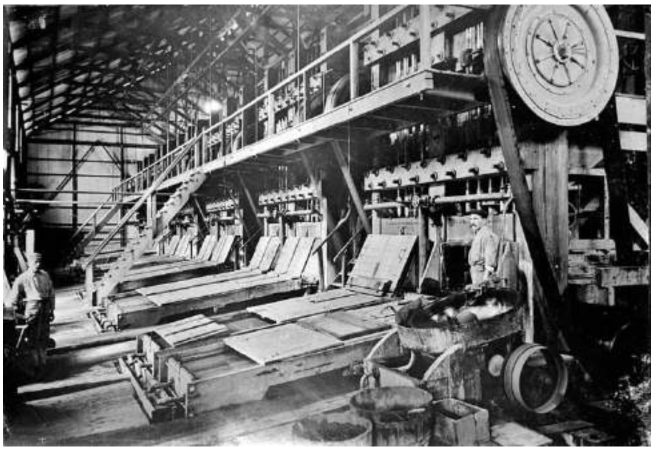


Figure 19: Sixty head stamp battery at the Mount Boppy crushing plant, July 1905.

Figure 20: Cyanide vats, Mount Boppy mine, 1905.

Figure 21: Treatment plant and slime pits Mount Boppy mine, 1905.

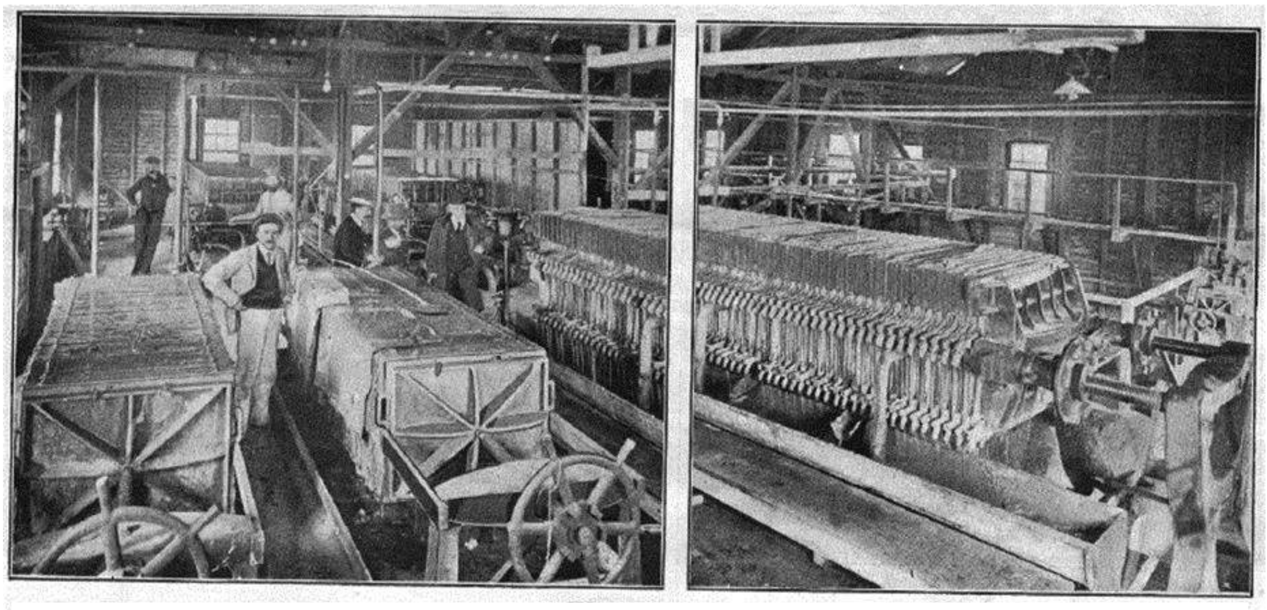


Figure 22: Filter presses in the gold extraction plant, Mount Boppy mine. Metallurgist Bill Williamson in foreground left. Source of photos: NSW Geological Survey Photo Collection and *Sydney Mail*, 13 July 1905.

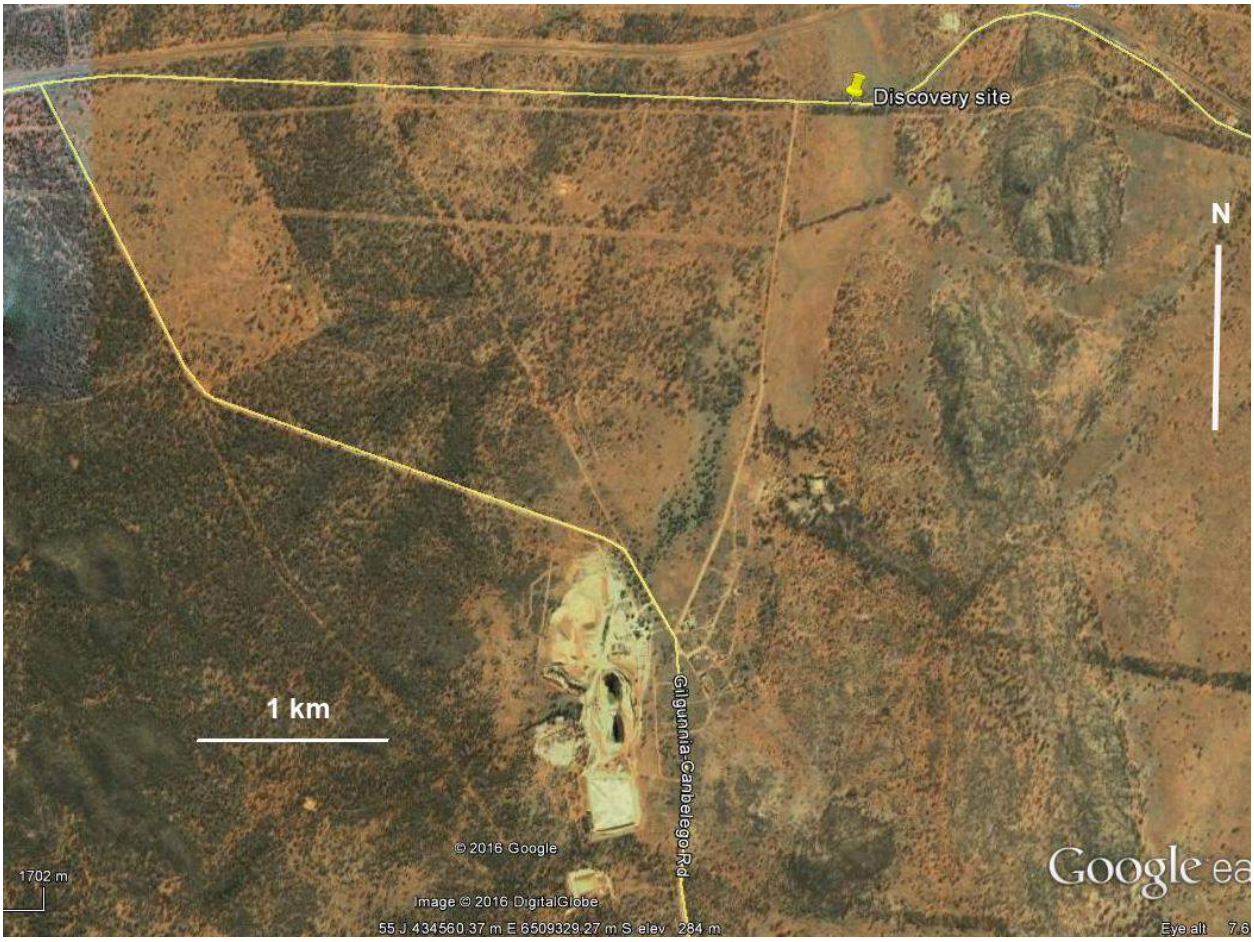


Figure 23: Google earth image of the Canbelego area showing the present Mount Boppy open pit mine on the east side of the township and the discovery site of gold-bearing quartz blocks, which were traced by Thomas Reid up the drainage in 1896.

Figure 24: View of the Mount Boppy open pit, March 2005, looking SE. Note historic workings and stope fill in eastern wall. Photograph by K. McQueen

McKinnons Tank Gold Mine

The renewed interest in gold in the 1980s led to a discovery which demonstrated that outcropping ore deposits could still be found in the heavily prospected Cobar region. During a stream sediment sampling program by Norgold Ltd in 1988, diligent geologists traversing a station track to McKinnons Tank, 37km SW of Cobar, observed and sampled a siliceous outcrop that assayed 4.2g/t gold. Follow-up mapping, soil geochemistry and a geophysical survey outlined a large gold anomaly, which was tested by drilling. The prospect was sold to Burdekin Resources in 1993 and further drilling established a resource of 2.2Mt at 1.9g/t gold.[36] Open pit mining commenced in 1995 and was completed in 1996, with stockpiled ore treated until mid-2000. The processing plant consisted of primary jaw crusher, SAG grinding mill and CIP extraction circuit. Mining exploited the oxidised ore in the deeply weathered regolith zone, with gold recovery from the ore of 92%. A deeper primary ore resource remains as gold hosted in pyrite, but this is too refractory and low grade to be economic at the present time. Over the 5.5 years of operation the McKinnons gold mine produced 131 000 ozs of gold.[37]

Figure 25: Open pit, McKinnons Tank gold deposit (view to NW). This is a pyritic quartz-vein stockwork system, exploited in the oxidised, supergene gold-enriched zone. Pit walls expose bleached saprolite with minor near surface ferruginisation (iron oxides) and deeper ferruginisation along faults/shears and bedding planes near weathered mineralisation. Primary pyrite is exposed in the lower left part of the pit. The deposit shows primary silicic and sericitic wallrock alteration and weathering-related alteration of sericite (mica) to illite (clay). Photograph by K. McQueen.

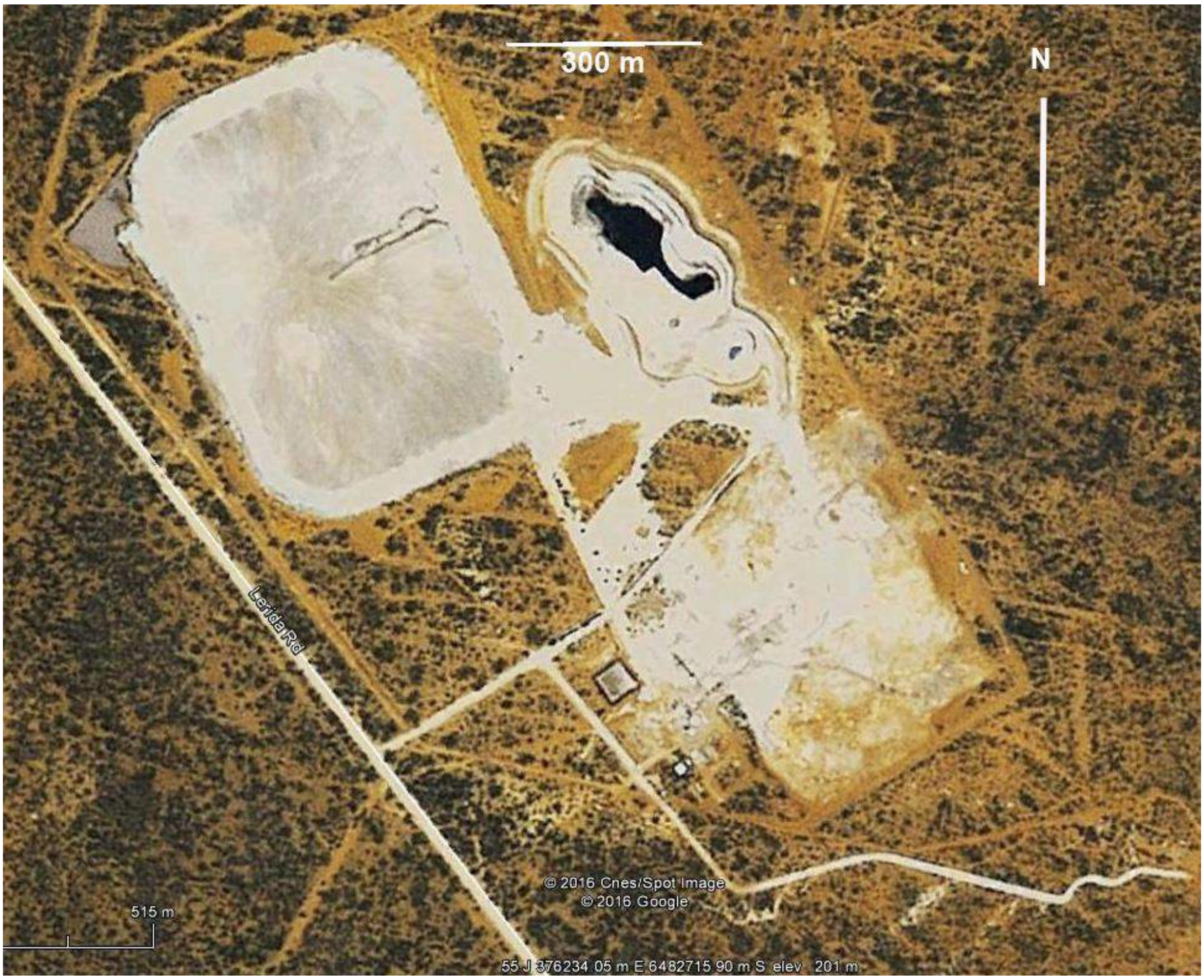


Figure 26: Google earth image of the McKinnons Tank gold mine 2016.

Mt Grenfell Historic Rock Art Site

The Mount Grenfell Historic Site contains important rock art of the Ngiyampaa Wangaaypuwan people. For thousands of years before European settlement people regularly visited the semi-permanent waterhole at the site and occupied the rock shelters formed in the ridges of Late Devonian sandstone and conglomerate (Mulga Downs Group). These overhangs are decorated with rock paintings featuring all facets of Aboriginal life. Many are linear paintings done by applying wet pigment with a fingertip or natural brush. Others are hand stencils. In some places, ochre and white pipeclay have been applied thickly and left to dry. More recent paintings have been superimposed over older ones. There are stick figures, human figures, images of birds and animals, medicine, food, the landscape and dreaming stories. This art remains deeply significant to Ngiyampaa people.

The Ngiyampaa (pronounced nee-yam-par) are dryland people associated with the arid plains and rocky hill country of Central West NSW bordered roughly by the Lachlan, Darling-Barwon and Bogan Rivers. The semi-permanent waterhole at Mount Grenfell was an important meeting place for generation after generation of this Aboriginal group. Following European settlement, Ngiyampaa people were moved to stations northwest of Wiradjuri country and in the 1930s, many were relocated again to Murrin Bridge, near Lake Cargelligo. On 17 July 2004, Mount Grenfell was handed back to the traditional owners and is now jointly managed with NSW

NPWS. Ngiyampaa people maintain strong connections with this area and continue to pass on cultural knowledge.[38]

Figure 27: Rock art at Mount Grenfell, featuring human figures. Photograph by K. McQueen.

The site is a short walk from the carpark. A more challenging walk (3.5km loop – Ngiyampaa walking trail)) can be made to a lookout with a view east across the Cobar basin plain including the headframe of the Endeavor Zn-Pb-Ag mine at Elura.

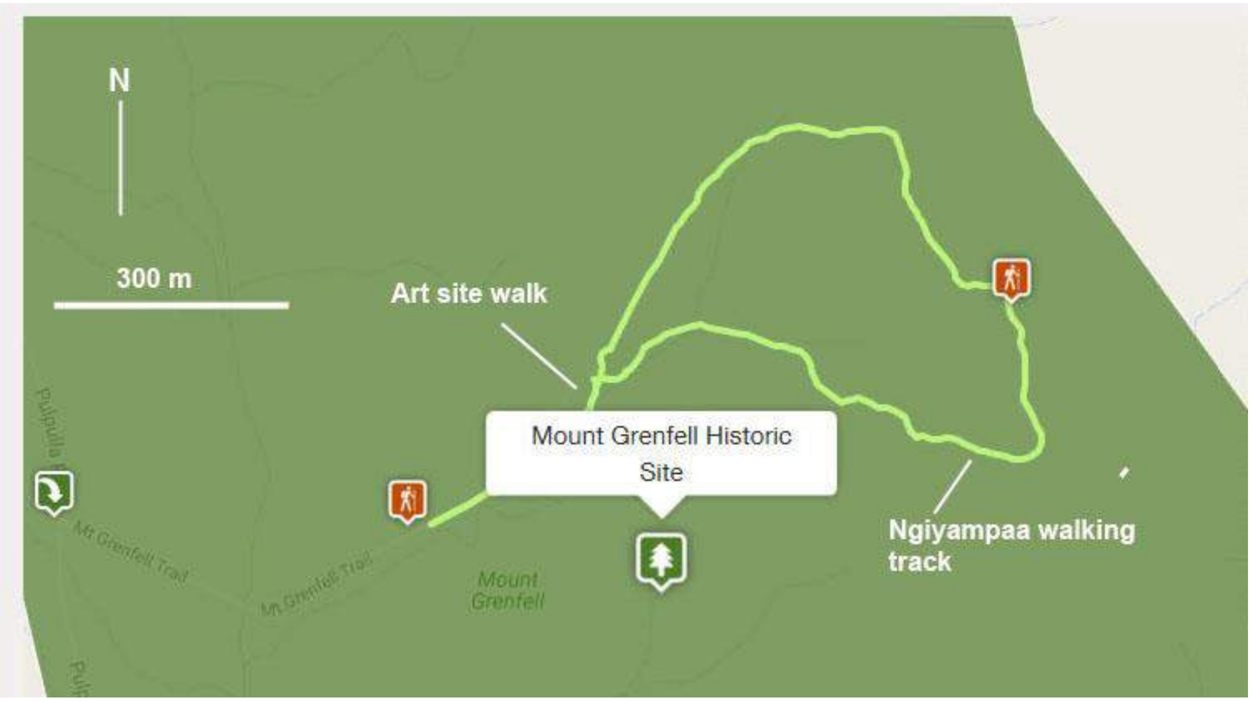


Figure 28: Sketch map of the Mount Grenfell Historic site. Source: NSW National Parks and Wildlife Service.

Nymagee-Hera Mines

Copper was found at Nymagee by two shepherds, Henry Manly and his mate Bryson in September 1876 while they were minding sheep near a small hill. They sampled the attractive green and blue copper carbonates and after advice from a boundary rider that this was copper ore, they re-examined the site the next day. The following month, Manly applied for a mineral conditional purchase claim of 80 acres.[39] Russell Barton, one of the major shareholders in the Cobar copper mine, visited the claim and was sufficiently impressed to buy it in 1880 for the modest sum of £1200.[40] In March 1880 Barton formed the Nymagee Copper Mining Company Ltd, which commenced rapid development of the mine.[41] Captain John Wills was appointed manager and by the end of the year had commenced three shafts on the main western lode and one on an eastern lode. Four reverberatory furnaces were constructed for on-site smelting of the rich carbonate and chalcocite ores that extended down to 48m depth.[42] In February 1883 the mine employed 109 miners and 200 woodcutters and carters and by 1885 was consuming 52,000 tons of wood annually to fuel eleven furnaces, two calciners and boilers for the steam engines.[43] Smelting had evolved to blending two thirds of calcined sulfide ore with secondary ore.[44] During this time the town of Nymagee developed next to the mine and eventually reached a population of 1200 in 1888.[45]

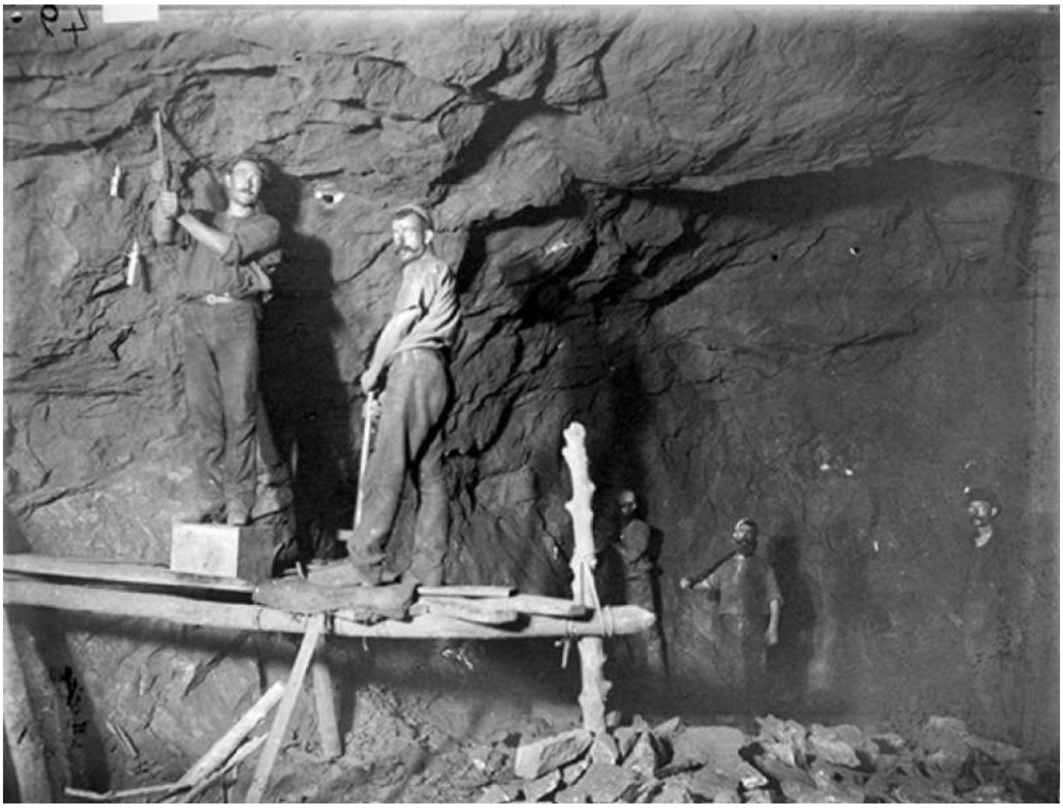


Figure 29: Miners on the 250 foot level, Nymagee mine ca. 1890s. Note lighting and OH&S standards. One miner appears to be standing on an explosives box. Source: NSW Geological Survey Photo Collection.

Operations continued successfully until 1893 when the mine was closed due to low copper prices. It was re-opened and worked on tribute in 1895 and then purchased by the Great Cobar Copper Mining Syndicate in 1896 for £10 000.[46] The new management substituted a blast furnace for ore reduction and subsequently established partial pyritic smelting in 1901, removing the need to heap roast the ore. The reverberatory furnaces were retained for matte roasting.[47]

In December 1906 the Syndicate sold the operation to a group of British investors who formed the Nymagee Copper Limited company. At the time of purchase the copper price was nearing a peak of £80 per ton, but the company decided to close the mine to totally replace the ramshackle plant and during this time the copper price dropped to £60 per ton.[48] Smelting recommenced in October 1907, and in August 1908 the nearby Crowl Creek and Shuttleton mines were purchased to provide siliceous ore to blend with that at Nymagee.[49] The low copper price, cost of transport and inability to convince the government to construct a branch railway line from Hermidale to Nymagee to reduce costs meant that the mine was unprofitable and closed down in 1908. The property was sold at auction for £15 000 and lay idle until 1912 when it was taken up by the Mouramba Copper Mine Ltd company.[50] The workings were dewatered and new plant installed before smelting commenced at the end of 1913. After a short period, operations were suspended due to drought and uncertainty in the copper market following the declaration of war in September 1914.[51] Mining recommenced in 1915 following the rebound in the copper price and continued until 1917 when the Nymagee mine was finally closed.[52] Total copper production from 1881 to 1917 was approximately 24 000t.

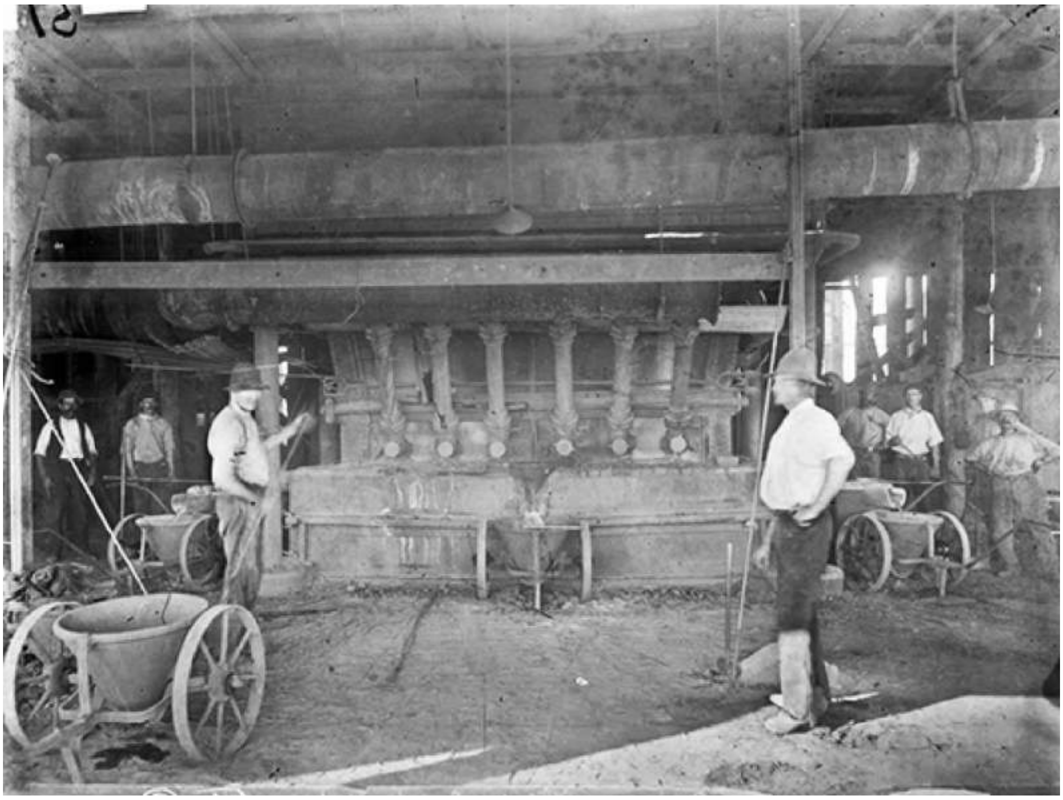


Figure 30: The water jacket blast furnace, Nymagee mine ca. 1901. Source: NSW Geological Survey Photo Collection.

The Nymagee area is experiencing a rebirth following sporadic exploration since the 1960s. Drilling in 1974 defined a remnant pillar resource at the Nymagee mine of 821 000t at 2.3% Cu and a total resource in the Pb-Zn lodes of 363 000t of 0.5% Cu, 3.0% Pb and 7% Zn, but too small for a stand along operation. Ore-grade polymetallic mineralisation was drilled by Pasminco in 2000 at the new Hera deposit 5km SE of Nymagee and further work by Triako Resources Ltd and Yunan Tin Company (now Aurelia Metals Ltd) has established an underground mine with high-grade gold and base metals.[53] Geophysical exploration and deep drilling by the latter group has also revealed significant extensions to the Nymagee deposit, below the old workings, with strong resemblance to the major C.S.A deposit north of Cobar.

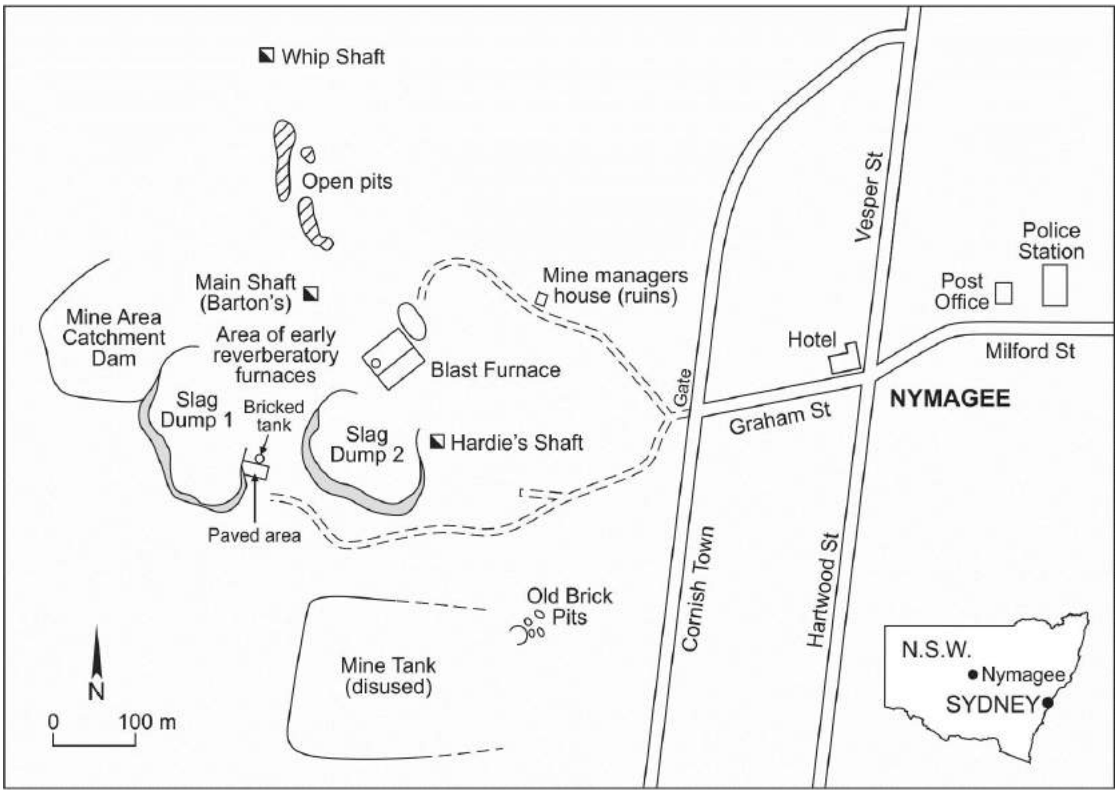


Figure 31: Plan of the current Nymagee mine site. Drawn by K. McQueen using Google earth as base.

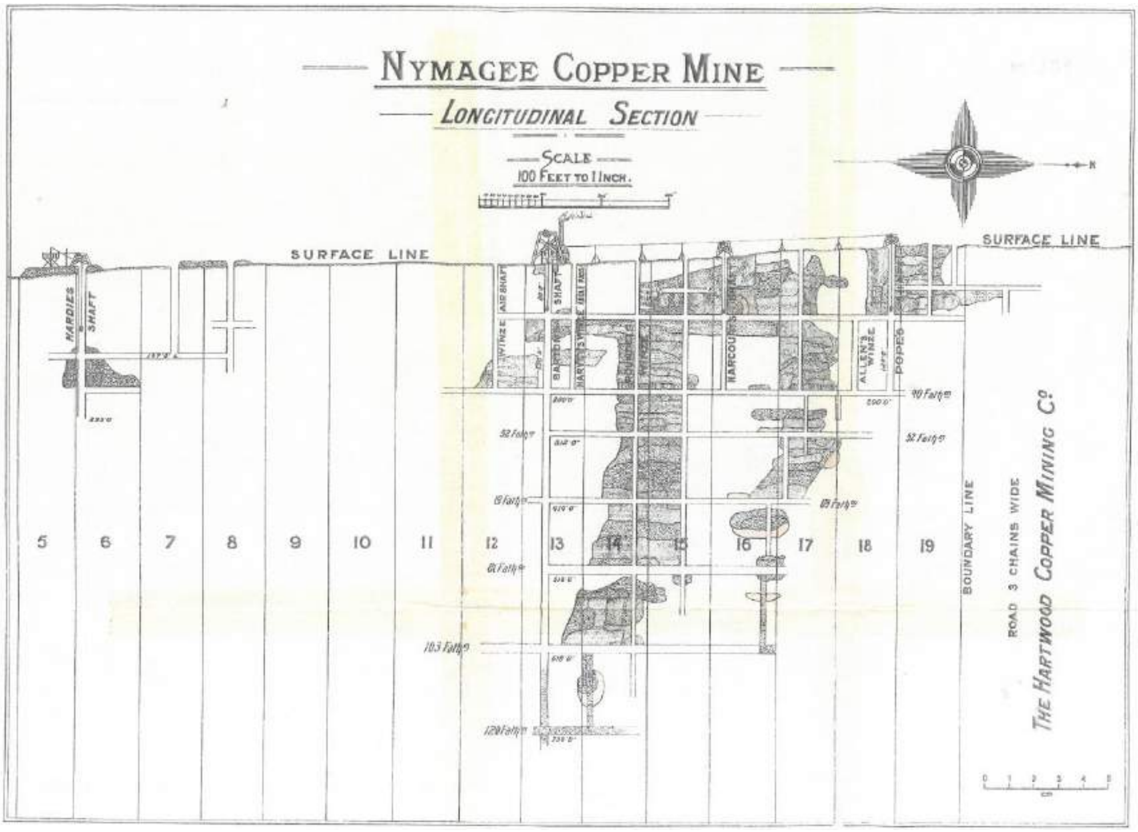


Figure 32: Longitudinal section of the Nymagee copper mine in 1890. Source: NSW Geological Survey, Nymagee Copper Mine, Nymagee, Mine Record 1881-1981 MR00138.

Figure 33: Google earth images of Nymagee and the Nymagee mine area.

Summary of geology

The Cobar region straddles the Palaeozoic central Lachlan Orogen of eastern Australia. It is bounded on its western margin by the Koonenberry - Kiewa Fault system (and the Koonenberry terrain) and in the east contains the major Gilmore Suture - Indi Fault Zone.[54] The essential geological elements are:

- an Ordovician basement, intruded by Silurian granites;
- the Late Silurian to Early Devonian Cobar Basin and associated rifts and volcanic sequences;
- a Late Devonian post-orogenic cover sequence;
- minor remnants of on-lapping Mesozoic sediments;
- Cenozoic regolith and minor leucitite lavas flows

The main basement features are shown in Figure 34. The oldest rocks are Early to Late Ordovician metamorphosed sedimentary rocks (Girilambone and Tallebung Groups).[55] The Girilambone Group occupies the eastern part of the region and consists largely of turbidites with some intermediate-mafic igneous rocks. These rocks have been multiply deformed and metamorphosed to variable grade. Rock types include quartzites, arenaceous meta-sediments, slates, phyllites, cherts, meta-basalts and altered tuffs. The Tallebung Group occurs in the south-eastern part of the region and contains a sequence of thick-bedded sandstones, carbonaceous mudstones and conglomerates and a sequence of thin-bedded sandstones, siltstones and carbonaceous mudstones.[56] This group has also undergone polyphase deformation, regional metamorphism, as well as local contact metamorphism.

West and south-west of Nyngan there are outcropping and buried mafic-ultramafic bodies (e.g. Rosedale, West Lynn, Honeybugle, Gilgai, Hermitage Plains). These consist of pyroxenites, gabbros and serpentinised rocks that can be grouped with the Alaskan-type zoned intrusions of the Fifield area (e.g. Owendale and Tout complexes). They are considered Early Silurian in age and linked to subduction of an older basaltic back-arc basin.[57]

The Ordovician basement has been intruded by an array of dominantly S-type, Silurian granite plutons. These are particularly extensive in the south-eastern part of the region. They include the Nymagee Igneous Complex (north-east of Nymagee), the small Tinderra, Wilgaroon and Wild Wave granite bodies (north-east and east of Cobar), the larger Erimeran Granite, Derrida Granite and Urambie Granodiorite batholiths and plutons (in the south) and the fault-bounded Thule Granite (near the south-west margin of the Cobar Basin). Most of these granites are muscovite-, and in some cases cordierite-bearing, with some pegmatitic, aplitic and microgranite phases. There are also minor hornblende- and biotite-bearing granodiorites. Small I-type granite intrusions of Siluro-Devonian age occur in the Byrock area. These outcrop poorly and are mostly highly felsic.[58] Swarms of Silurian-Devonian gabbroic dykes intrude some basement areas (e.g, in the Erimeran Granite and north of Girilambone).

The dominant geological feature of the region is the Cobar Basin, which formed in the Late Silurian to Early Devonian as a back-arc, intracratonic basin with deep-water troughs and flanking shallow-water shelves (these include the Cobar Supergroup).[59] This basin was inverted and structurally deformed in the late Early Devonian, with a second deformation in the Mid-Carboniferous.[60] Initial deformation resulted in NW-trending folds, development of a regional N-S cleavage and eastwards thrusting. Further deformation produced overprinting NE-trending folds and left lateral faulting. The main rock units include cleaved and weakly metamorphosed (to greenschist facies) trough sediments deposited during initial basin rifting (Nurri, Mouramba and Lower Amphitheatre groups) and subsequent sag-phase development of the basin (Biddabirra Formation and Upper Amphitheatre Group). These generally deep marine units consist of various turbiditic sandstones, siltstones and mudstones (or slates) with some basal, matrix supported conglomerates, local felsic volcanic rocks and minor limestones. The shelf sediments (Kopyje, Winduck and Walters Range groups) consist of shallow-water siliclastic sediments, limestones and volcanoclastic sediments.

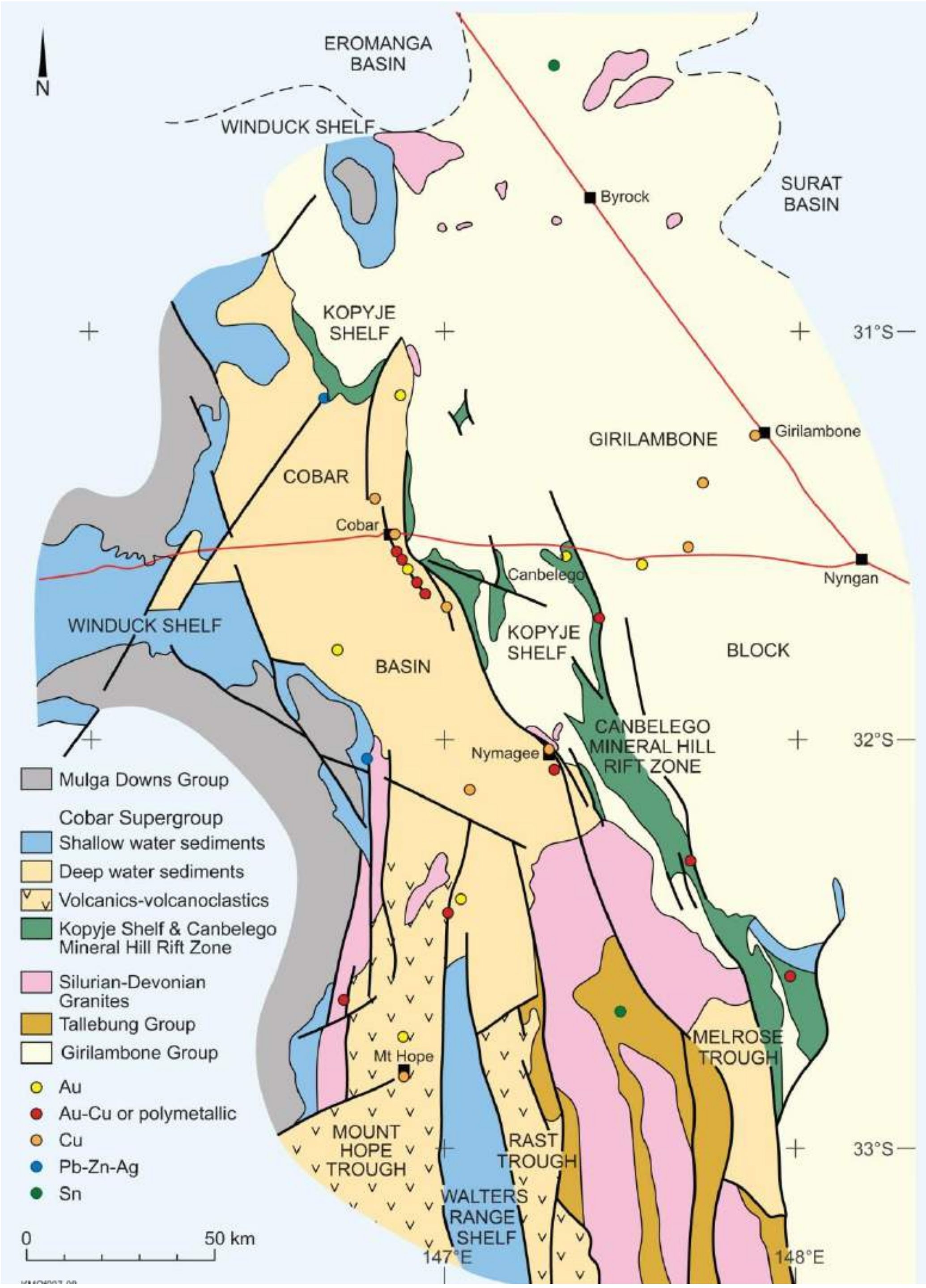


Figure 34: The geological framework of the Cobar region and location of significant mineral deposits (adapted from David 2005 and 1:250 000 metallogenic maps; Byrnes, 1993; Suppel and Gilligan, 1993; Gilligan and Byrnes, 1995).[61]

South of the Cobar Basin are the parallel Mount Hope and Rast Troughs, which represent narrow volcano-tectonic rifts.[62] These contain Early Devonian subaerial and submarine bimodal volcanic rocks, high-energy turbidites, some shallow water sediments and intrusive felsic porphyries and dykes (Mt Hope Group and Rast Group).

East of the Cobar Basin is the related Canbelego-Mineral Hill rift zone, which contains siliclastic sediments, volcanoclastics and felsic volcanic rocks (Baledmund Formation, Florida, Babinda and Majumba Volcanics).[63] To the south these grade into deeper water sediments of the Melrose Trough.

A Late Devonian sequence of dominantly fluviatile conglomerates, sandstones, siltstones and shales (Mulga Downs Group) overlies the Winduck Shelf to the north-west and south-west of the Cobar Basin.[64] The thick-bedded, coarser grained sandstones and conglomerates of the Mulga Downs Group generally show well developed cross bedding and sharp erosional channel bases. The conglomerates typically contain abundant, well-rounded and well-sorted pebbles of white vein quartz and quartzites. This sequence marks the transition from a dominantly marine to emergent (terrestrial fluviatile) environment.

Small remnants of possible Jurassic and Cretaceous river and lake sediments occur across the region. Extensive shallow marine sediments of the Cretaceous Eromanga and Surat basins overly Palaeozoic rocks to the north and north-east. Cenozoic deposits are widespread and include clays, sands and gravels infilling palaeochannels, and alluvial/colluvial deposits forming fans, depositional and erosional plains. North-east of Cobar, near El Capitan and Byrock, there are remnants of Early Miocene leucitite lava flows and eruption plugs.[65]

Regolith is widespread and dates to at least the Palaeocene. It includes variably eroded, deep weathering profiles, clays sands and gravels infilling palaeochannels and alluvial/colluvial deposits forming fans, depositional and erosional plains. North-east of Cobar, near El Captian and Byrock, there are remnants of weakly weathered Early Miocene leucitite lava flows overlying deep weathering profiles. Soils are mainly massive red earths grading to brown and grey soils towards the south (Walker, 1978). They are commonly calcareous and contain significant wind-blown dust. Sheetwash and wind erosion have removed up to 0.5m of the soil profile since European settlement.

Mineral deposits

The Cobar region is a major metallogenic province for hydrothermal copper, gold and lead-zinc-silver mineralisation. Major deposits are largely epigenetic-hydrothermal or volcanogenic in origin. Other potential deposit types include palaeochannel placer deposits (PGE, gold, tin, iron), residual deposits (nickel, PGE, scandium, REE), clays, refractories, limestone and construction materials (Table 1). Known mineral deposits are compiled on the Bourke, Cobar and Nymagee 1:250 000 metallogenic maps, as well as the recently published Cobar 1:500 000 Special metallogenic map, and documented in the accompanying notes.[66]

Ore deposits in the Cobar Basin represent a continuum from high temperature (possibly deeper formed), structurally controlled, hydrothermal systems in high strain zones to lower temperature, stratigraphically controlled (strata-bound) systems, with related feeder veins and stockworks. The high temperature systems have a multi-stage paragenesis with different metal associations for the different stages. This has resulted in separate gold-, copper- and zinc-lead rich deposits or zones of different metal combinations at some deposits. Examples include the C.S.A., Great

Cobar, New Cobar (Figure 35), Chesney, New Occidental, the Peak, Perseverance, Nymagee and Hera deposits. The stratabound deposits and vein stockworks have some similarities to Mississippi Valley type and epithermal deposits respectively. Examples are the Wonawinta and Gundaroo zinc-lead-silver prospects and the McKinnons gold deposit. The Elura lead-zinc-silver deposit is an example of a system somewhere between the main end members. The typical Cobar-style deposits of the eastern Cobar Basin consist of multiple lenses in steeply plunging, pipe-like clusters. They are localised along major shear and thrust fault systems at dilation sites, particularly in zones of juxtaposed rocks with contrasting competency.[67] The deposits have great depth extension but a small surface footprint and are very small surface targets (typical strike lengths 250-300m). Their polymetallic composition favours a multi-element approach to geochemical exploration and some have been found from their magnetic signatures. The strata-bound systems are broader targets, but do not have magnetic signatures. Small gold-bearing, hydrothermal quartz vein deposits also occur in Early Devonian meta-sedimentary rocks within the Cobar Basin (e.g. at Mount Drysdale and Gilgunnia).

Figure 35: Open pit, New Cobar gold-copper deposit (view NW). This is a Cobar-style deposit hosted by siltstones-sandstones of the Great Cobar Slate. It is structurally controlled and localised in a NNW-trending shear zone with associated ‘pebble’ shears. The top five benches are in oxidised and leached saprolite showing strong ferruginisation, particularly along fractures. The lower section is weakly oxidised saprock. Major quartz vein (near old workings) post-dates the main mineralisation. Photograph by K. McQueen.

The volcanic dominated sequences of the Canbelego-Mineral Hill rift zone and the Mount Hope trough contain volcanic-associated massive sulphide (VMS) deposits, hydrothermal replacement deposits and small hydrothermal veins. Examples of volcanic-associated deposits include those at Mineral Hill, the Pipeline Ridge prospect, south of Canbelego and other small base metal sulphide deposits associated with the Florida Volcanics at Canbelego. The Shuttleton and Mt Hope copper deposits may also be volcanic-associated systems.[68] The Mount Boppy gold deposit, developed in faulted and brecciated meta-sedimentary rocks at Canbelego, is a hydrothermal replacement deposit with epithermal characteristics.

The Ordovician basement rocks contain a range of deposit types. The most important are pyritic copper-rich sulphide deposits in the Girilambone Group, developed between Girilambone and Hermidale (e.g. Murrawombie, Tritton, Budgerygar and Budgery deposits). These deposits have been described as volcanogenic in origin (Besshi-type)[69] although they clearly have a strong structural control or overprint and similarities to the Cobar-style epigenetic hydrothermal deposits. Small quartz-vein gold deposits occur in the Girilambone Group (e.g. Muriel Tank and Restdown goldfields). These are structurally controlled, slate-hosted mesothermal deposits. At Mount Dijou and Bald Hills in the far north of the region, mafic volcanic rocks of possible Ordovician age host small vein and lode-style gold deposits. Tin-bearing quartz veins occur in the Tallebung Group and associated S-type granite intrusions near Tallebung.

Intrusion-related deposits occur in association with the various granites of the region. These include skarn deposits, such as the copper-tin mineralisation at Doradilla, and minor mineralisation around a sub-cropping granite body at the Beanbah prospect north-east of Cobar. Drilling has intersected disseminated base metal sulphide mineralisation associated with granitic rocks at the Sandy Creek prospect, south of Cobar.[70]

Placer deposits have generally been neglected as potential exploration targets in the Cobar region. Minor alluvial gold has been worked in the upper parts of Whitbarrow Creek, north of Nymagee and on the eastern side of Mt Drysdale. Alluvial tin was worked in the Tallebung tin field and alluvial gold and platinum (20,000 ozs) were extracted from deep lead palaeochannel sediments eroded from primary mineralisation in the Alaskan-type ultramafic-mafic intrusions at Fifield, south-east of the region.[71]

Residual deposits formed by intense weathering of mafic-ultramafic intrusions are potential exploration targets, particularly in areas under cover. There has been exploration for residual nickel, PGE (platinum group elements) and scandium mineralisation in the eastern portion of the region and to the south. There is some potential for kaolinite deposits and refractories (e.g, silcrete), in weathering profiles and palaeo-lake deposits. Leucitite is currently being quarried for road aggregate near Byrock and small limestone bodies have been worked in the past.

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Table 1. Ore deposit types and potential exploration targets in the Cobar region.

Age	Sequence	Deposit Types			
Early Miocene	Leucitites	Aggregates	Mantle minerals		
Cenozoic	Palaeochannel systems	Placers Au, Pt, Sn, Fe	Construction materials		
Cenozoic	Weathering profiles	Clays Silcrete	Residual Ni, Sc, REE	Supergene Au, Ag, Cu	
Late Devonian	Mulga Downs Group	Red Bed U-Cu ?	Quartz pebble aggregates		
Early Devonian	Florida, Babinda Majumba Volcanics	VMS Cu-Pb-Zn±Au	Veins and stockworks Cu-Pb-Zn ±Au		
Early Devonian	Baledmund Formation	Hydrothermal replacement Au			
Early Devonian	Cobar Supergroup	Structurally controlled hydrothermal Cu, Au Pb Zn Ag	Stratabound hydrothermal Zn-Pb-Ag±Cu	Mesothermal veins and stockworks Au	Deformed VMS Cu±Pb-Zn-Ag ±Au
Siluro-Devonian	I-type granites	Skarn deposits Cu-Sn Cu-Pb-Zn±Au			
Siluro-Devonian	S-type granites	Greisen veins Sn	Porphyry-related Cu-Pb-Zn		
Early Silurian	Zoned mafic-ultramafic intrusions	Alaskan-type magmato-hydrothermal PGE			
Ordovician	Girilambone Group	Structurally controlled hydrothermal Cu	Possible VMS 'Besshi' type Cu	Structural mesothermal veins Au	
Ordovician	Tallebung Group	Hydrothermal veins Sn			

VMS = volcanic associated massive sulphides

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