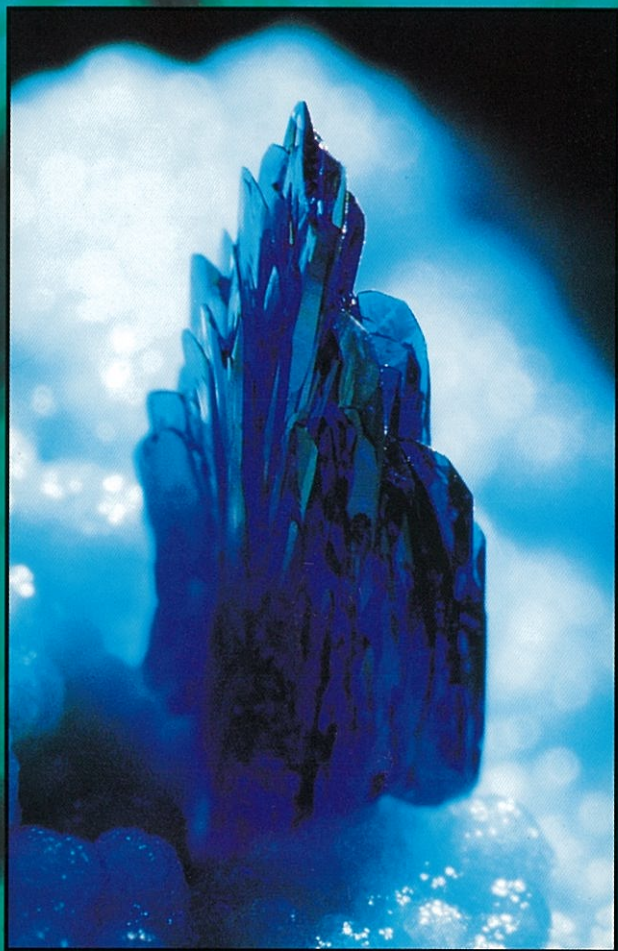
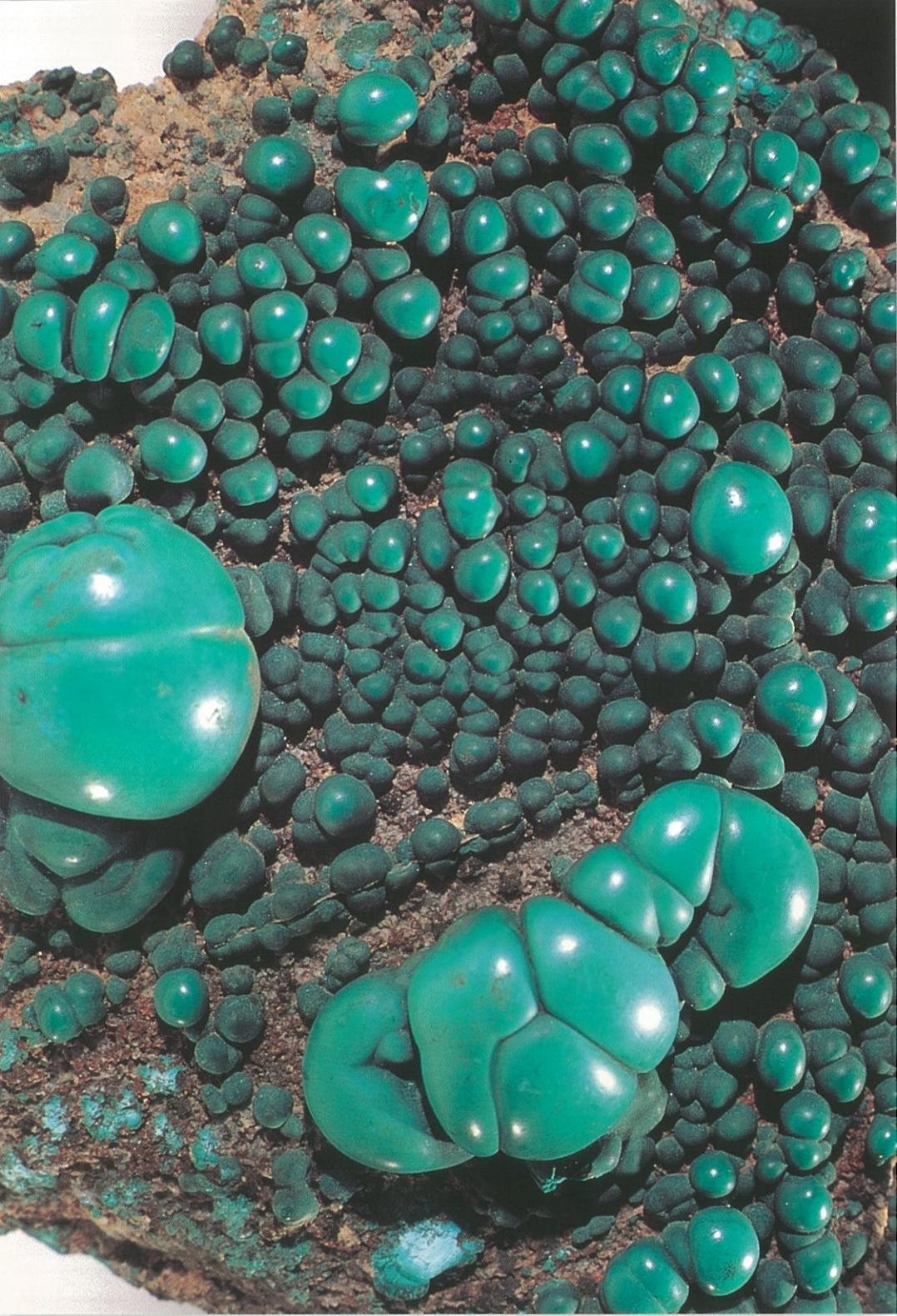


Minerals of the Burra Mine, South Australia



MINES AND ENERGY
SOUTH AUSTRALIA





Minerals of the Burra Mine, South Australia

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South Australian Museum

and

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Mines and Energy South Australia

Special Publication No. 11

MINES AND ENERGY SOUTH AUSTRALIA

COVER PHOTO: Group of bladed, 5 mm azurite crystals on chrysocolla. (Photo no. 23547)

Background: Polished slab of malachite showing concentric banding.

(Photo no. 42370)

INSIDE COVER: Botryoidal malachite on matrix, presented to the South Australian Museum by Sir Henry Ayers in 1881. The portion shown is 110 by 70 mm. (Photo no. 42371)

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INTRODUCTION

European settlement of South Australia began in 1836. It was conceived as a great social experiment: there was to be no convict labour, and the proceeds of land sales were directed into a migration fund to bring workers and their families from Europe to provide a labour pool for the new colony. But the economic basis of this utopian dream was flawed as there were insufficient funds for the public works needed to establish the colony, and within a few years the young settlement of South Australia was on the verge of bankruptcy. It was the discovery of rich copper deposits, first at Kapunda in 1842 and then the more significant discovery at Burra in 1845, that saved the colony from financial disaster and established it on the road to prosperity.

Burra was Australia's first great mine and at the time was one of the largest and richest in the world, producing nearly 5% of the total world copper. Today the mine is still famous for the beautiful specimens of bright green malachite and blue azurite which adorn the exhibitions of the world's leading mineralogical museums.

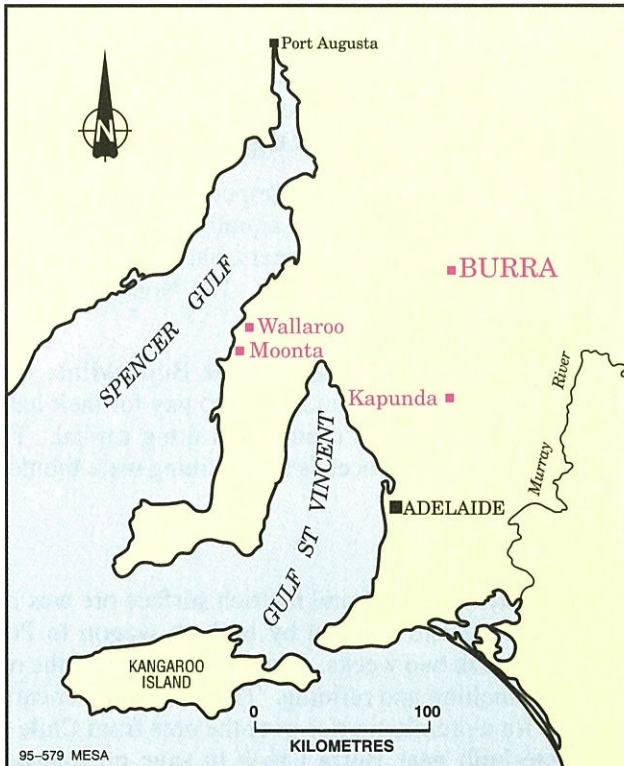


Figure 1. Location map showing Burra and the other major copper mining centres in South Australia.

BRIEF HISTORY OF THE MINE

Discovery

The story of the Burra Mine began with the chance discovery of copper ore by a shepherd, William Streair, near Burra Creek in 1845. Soon after, a similar find was made by Thomas Pickett, also a shepherd, 13 km to the north. News of the shepherds' discoveries reached Adelaide, a town already infected with mining mania because of the recently opened Kapunda Mine. Streair sold the location of his find to an Adelaide merchant for £8, and this deposit became the Princess Royal Mine. Pickett received £10 for revealing the location of the large mass of copper ore that he found, and this later became the Burra Mine. A struggle for possession of the land containing the two copper deposits quickly followed.

The interested parties formed into two groups who refused to join forces and they were immediately dubbed the 'Nobs' and the 'Snobs'. The Nobs were capitalists and pastoralists, and included the owners of the Kapunda Mine. The Snobs were the shopkeepers and merchants from Hindley Street, Adelaide, who had formed the South Australian Mining Association (SAMA). Under regulations for buying land in the colony at the time, mineral rights to the deposits could only be obtained by purchasing the mineral bearing land and, since the deposits were outside the already surveyed areas, a Special Survey of 20 000 acres was required at a cost of £20 000. Both the Nobs and the Snobs tried unsuccessfully to raise the necessary funds independently and thus gain control of both deposits.

Eventually the rival groups were forced to cooperate and they jointly paid for the Special Survey and agreed to divide the land equally, with each half containing one of the copper deposits. Neither party, it appears, had any particular preference for which deposit they mined, so lots were drawn. The Nobs drew the southern half, naming their mine Princess Royal.

The northern half, drawn by the Snobs, became the Burra Mine. SAMA had paid up capital of £12 320. Ten thousand pounds went to pay for their half of the special survey and the remaining £2 320 was used for working capital. This was all the capital the Burra Mine needed; the proceeds from mining were fabulous, and funded all future development at the mine.

Growth of the Mine

Mining began in September 1845 and the rich surface ore was easily quarried; it was sorted by hand and shipped by bullock wagon to Port Adelaide, a journey of 150 km which took two weeks. From Port Adelaide, the ore was shipped to Swansea, Wales, for smelting and refining. The Burra copper carbonate ore was easy to smelt, and sold for a premium price over the ores from Chile and Argentina. In 1849, smelters were built near Burra Creek to save on transport costs. The smelters required 600 tons of firewood each week and within a few years the area around the mines was almost totally denuded of trees.

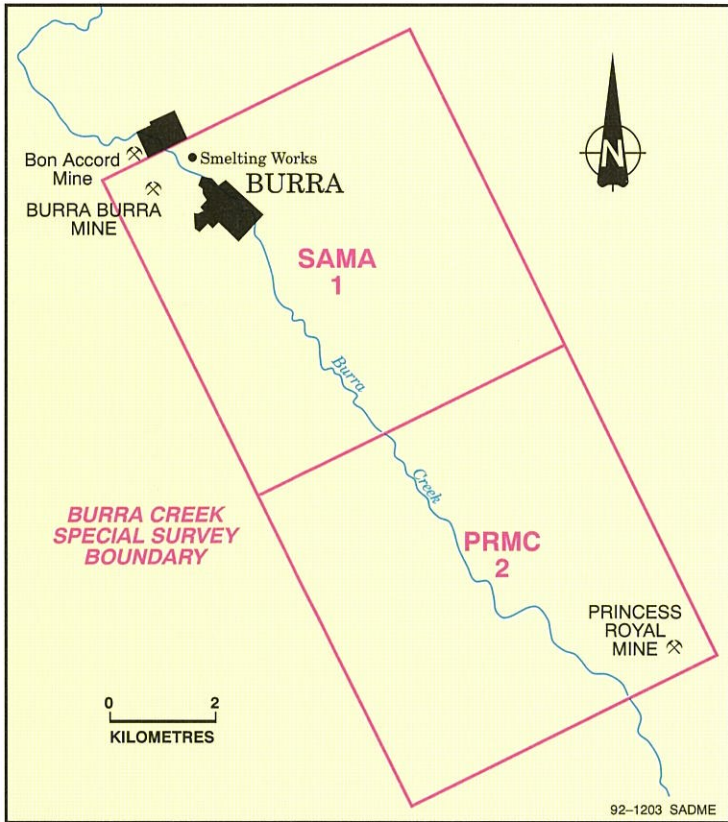
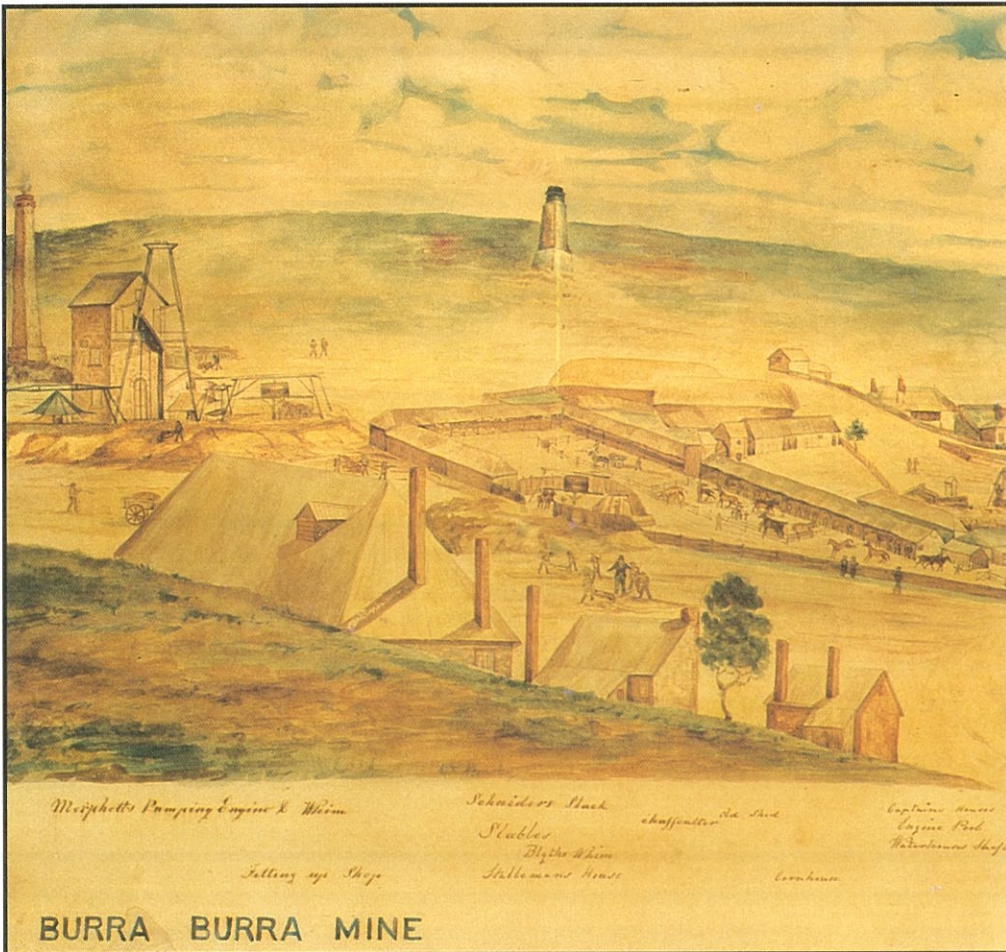


Figure 2. Map showing the area covered by the Special Survey and the location of the Burra and Princess Royal copper deposits. The Snobs (SAMA) drew the northern section and their fortunes were made by the Burra Mine. The Nobs drew the southern half of the survey area which included the Princes Royal Mine. Their mine had a large outcrop of rich carbonate ore but this did not extend to depth.

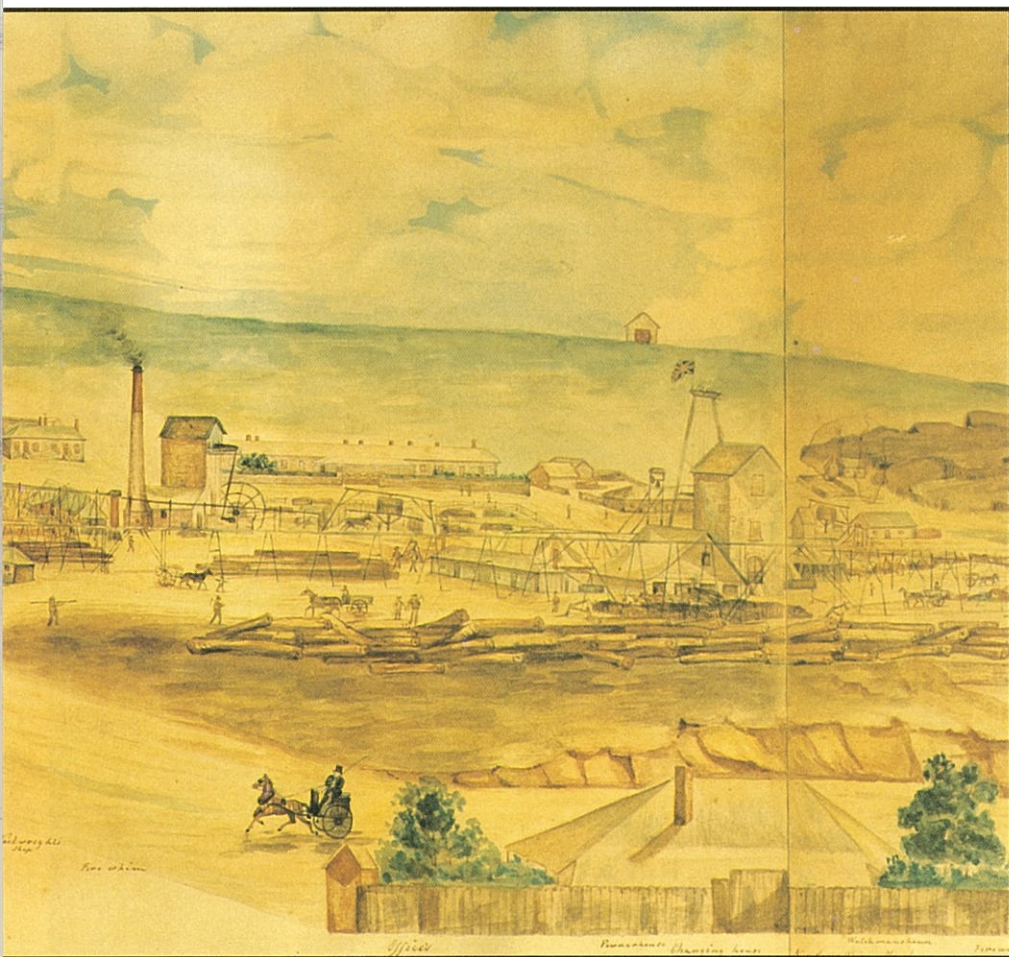
By 1850, Burra was the largest metalliferous mine in Australia and employed more than 1 000 men and boys. The management and the majority of miners were Cornishmen, and the mines were worked under the traditional Cornish tribute and tutwork employment systems. Production declined after 1860 and eventually underground mining ceased in 1867. From 1870 until closure in 1877 it was worked by the open-cut method but this proved unprofitable. In the early years, the ore grade was more than 20% copper. During the 30 years of production between 1845 and 1877, some 700 000 tons of ore were raised, yielding over 50 000 tons of copper at an average ore grade of more than 7%. The cost of mining averaged £40 per ton of copper. The shareholders in SAMA received over £800 000 in dividends, and the Government only the £10 000 from the original Special Survey. Thomas Pickett, the discoverer, received only £10 for revealing the location of the deposit.



Princess Royal Mine

The Nobs, who drew the southern half of the Special Survey, at first thought they had the more valuable deposit. The first large ore parcels shipped to England returned nearly 30% copper but the deposit did not extend to any great depth. Mining reached the watertable at about 60 m below the surface in 1851. The company was faced with a major capital outlay to install pumps and, with falling ore reserves, was forced to close the mine. In its brief six-year life it produced only 1 000 tons of copper. The mine and the rest of the 10 000 acre selection were sold freehold for grazing, and the original investors were thus able to recover 13 shillings in the pound of their original investment. Few specimens from this mine exist in collections.

View of the Burra Mine in 1858 by William Bentley. From left to right are Morphetts Enginehouse, mine stables, captains' cottages, Peacocks Enginehouse, mine offices and Schneiders Enginehouse. (Photo no. 39298)

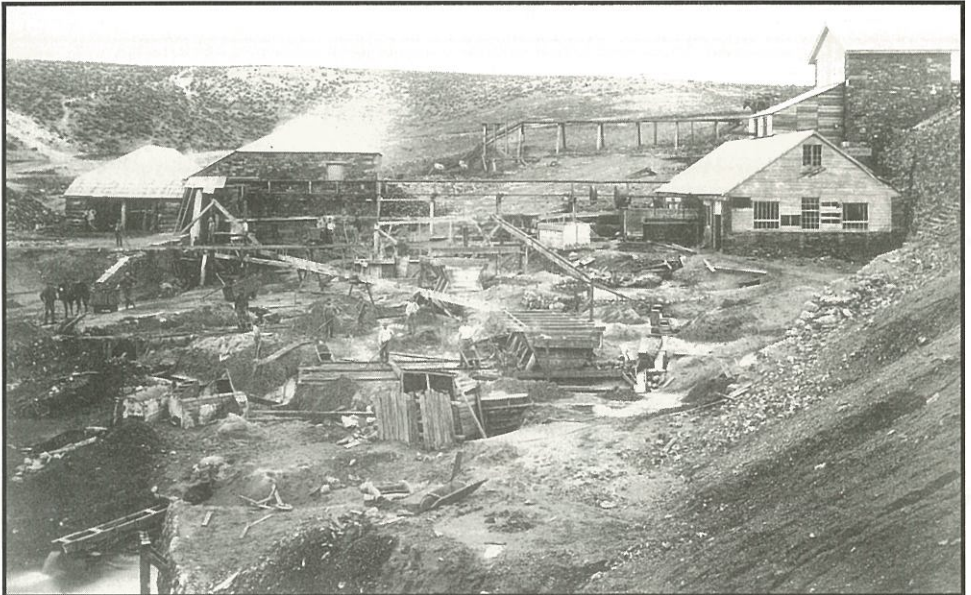


Ore dressing at the Burra Mine



ABOVE: Ore dressing floors, c. 1865, containing numerous rows of hand-operated jiggers. (Photo no. 12975)

BELOW: Ore dressing tower, 1875. Mechanised ore dressing machines were introduced at Burra in 1870. (Photo no. 32149)



Battling Rising Water

The battle against rising water levels was a major problem at all of South Australia's major copper mines in the 19th Century. As depth of mining increased so did the problem of keeping the mines dry. At Burra, the watertable is only 36 m below the surface and was soon reached. At first, horse whims and buckets were used to bail the water and keep the workings dry. By 1849, horse whims were no longer sufficient and steam pumping engines were needed. The first pumping engine was installed on Roachs Shaft to control the water and allow deeper stopes to be worked. An even more powerful engine was installed on Schneiders Shaft in 1852, but the Victorian gold rush intervened (see Birch, 1987) and this engine was not commissioned until 1854. For every ton of ore raised, one and a half tons of water were pumped from the mine.

The engines were of the Cornish beam type, derived from Thomas Newcomen's invention in the early 1700s and improved by James Watt in the late 18th Century to pump water from the copper and tin mines of Cornwall. These steam-powered engines, some with cylinders 80 inches in diameter, were exported around the world and used extensively to control water in South Australia's copper mines. Each engine was housed in a specially built stone enginehouse; three remain at Burra (Drew, 1987, 1988).



Morphetts Enginehouse, 1875. (Photo no. 35888)

Henry Ayers

Perhaps the best known figure associated with the Burra Mine was Henry Ayers. Born in England in 1821 of humble origins and trained as a law clerk, Ayers became company secretary of the South Australian Mining Association at the age of 24 and was in effective control of the mine for most of its 30-year life. Ayers ran

the mine from Adelaide, sending detailed written instructions to Captain Henry Roach, the resident manager at Burra. Not initially a large shareholder in the Mining Association, Ayers slowly acquired more shares and other business interests, and held directorships in the Bank of Adelaide and a number of other companies. At his death in 1897, he was one of the wealthiest men in South Australia.

Henry Ayers entered the colonial parliament in 1857 and served as a minister on eleven occasions, and was Premier seven times during one of South Australia's most politically turbulent periods. He was knighted in 1872, and a year later Ayers Rock in central Australia was named in his honour by the explorer W.C. Gosse. In 1881, he presented a fine collection of specimens from Burra Mine to the South Australian Museum.

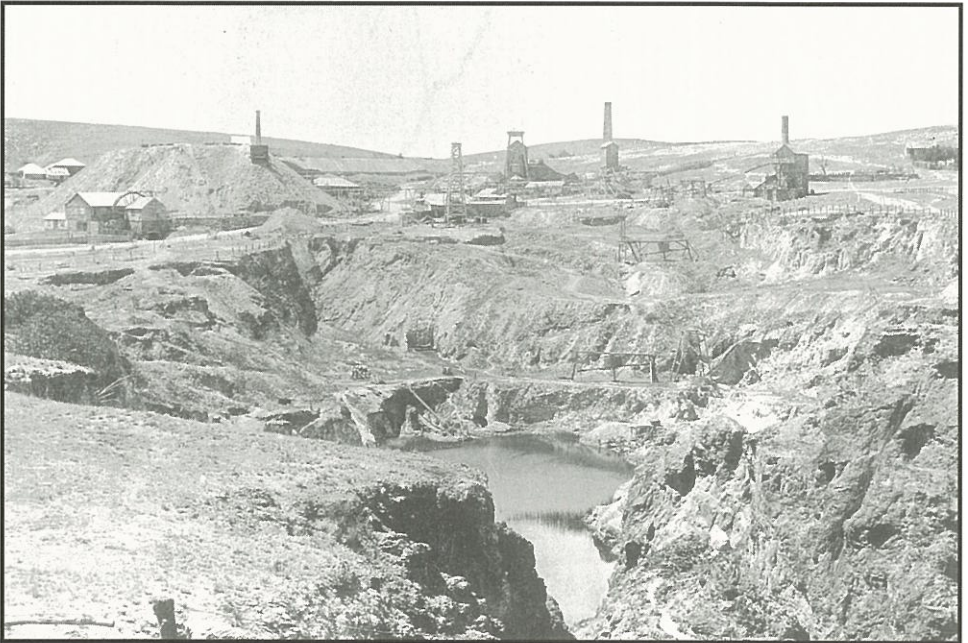
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TOP: Burra open cut, 1875, looking north down the inclined railway used to haul ore to the ore dressing tower. (Photo no. 12974)

BOTTOM: Burra Mine, c. 1904. Material from the open cut was hauled up an inclined railway to the top of the mullock dump (left). Peacocks Enginehouse, demolished in 1972, is on the right. (Photo no. 32144)



Sir Henry Ayers, c. 1880. He was in effective control of the Burra Mine for nearly 30 years. He was also active in colonial politics and was Premier of South Australia on seven different occasions. (Photo no. 42398)



A Mine Reborn

In 1969, nearly a century after the mine closed, Burra was reopened and worked as an open cut. Between 1969 and 1981 it produced two million tons of ore, nearly three times as much as was mined between 1845 and 1877. The ore, however, yielded only 25 000 tonnes of copper metal, the average ore grade being 1.25% metal compared to over 7% during mining operations last century. It is somewhat ironic that it was the change to open-cut mining in the 1870s that caused the mine to close.

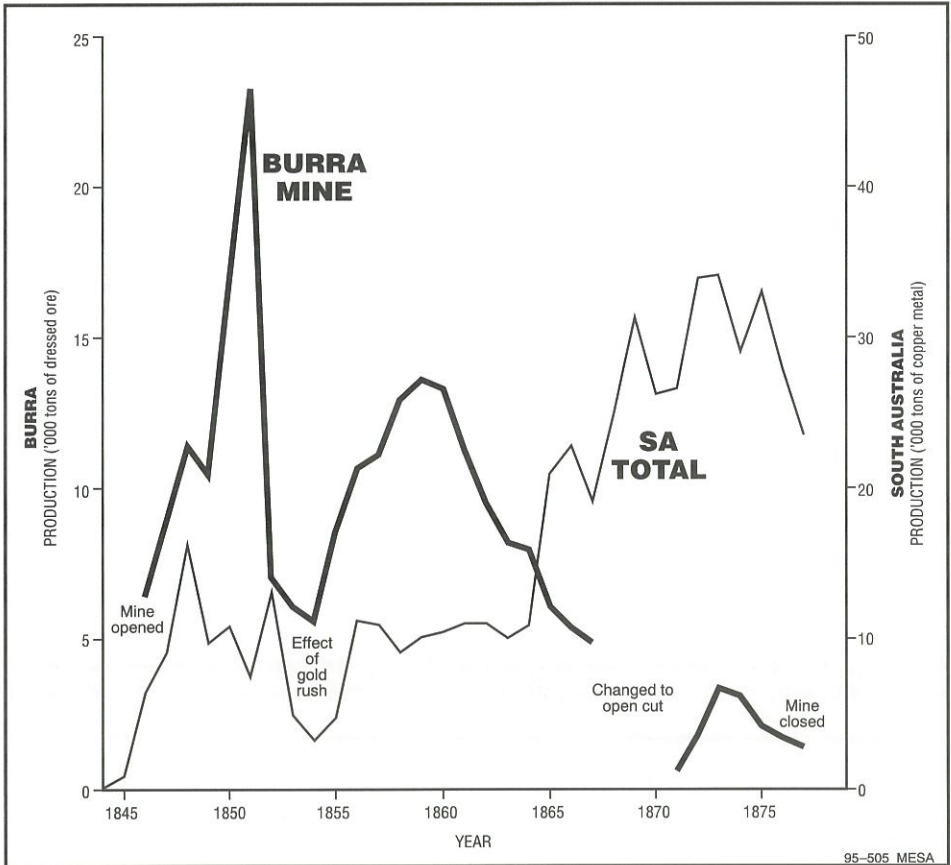


Figure 4. Production of dressed ore from the Burra Mine compared to South Australian production of copper metal for the period 1845-77.

Burra Mine Today

Today the mine is an important historical site and substantial physical evidence of mining and processing operations remain. The old mine buildings represent mid-nineteenth century copper mining and processing on a greater scale than in any other site in Australia. The Burra Mine Museum was established in 1986 to help conserve and interpret these remains in an open-air historic park environment. The feature of the Museum is Morphetts Enginehouse which was reconstructed in 1986 and was the first Cornish beam enginehouse to be restored in the world (Drew, 1987). This was followed by retimbering of the upper section of the adjacent engine shaft, and excavation and retimbering of a drainage adit. The project has continued with archaeological excavations and conservation of other ruins including Morphetts beam windinghouse, an ore dressing tower, crusher house, and powder magazine. A feature of the museum is interpretive signposting which creates an understanding of the historic evidence remaining using historic photographs and reconstructions.

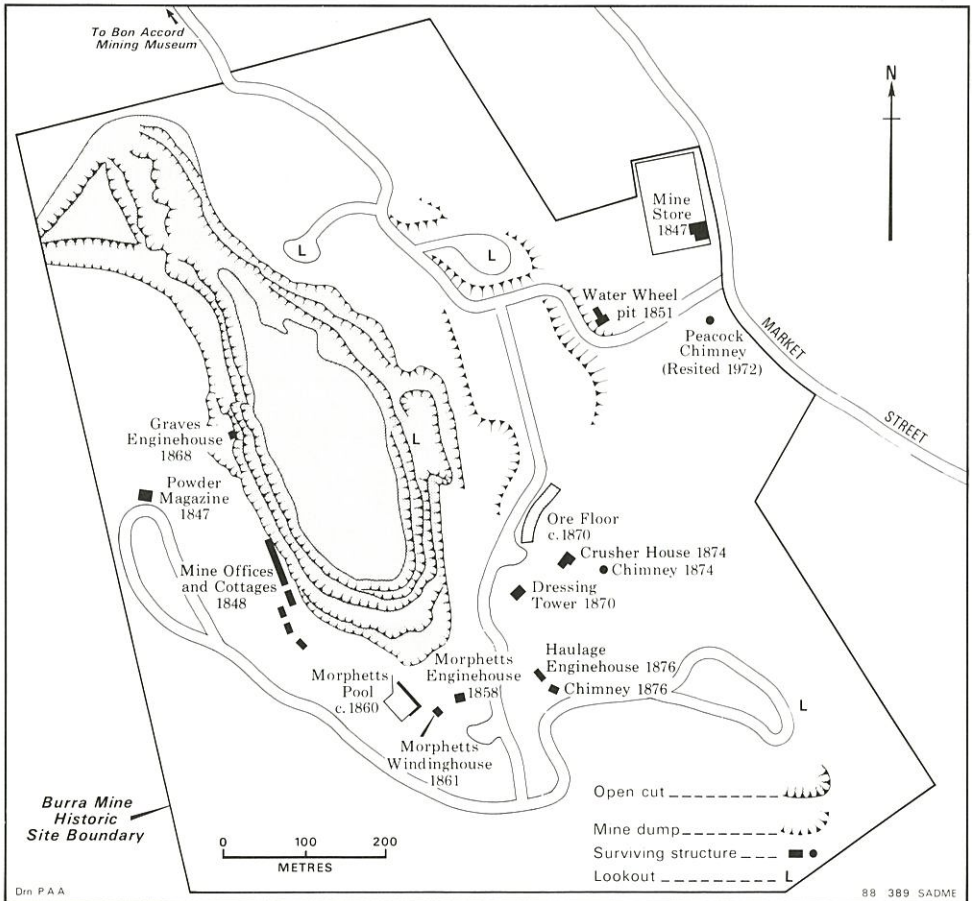


Figure 5. Burra Mine historic site showing the surviving structures and open cut.

GEOLOGY OF THE BURRA COPPER DEPOSIT

The Burra copper orebody lies on the side of low limestone hills situated in a broad valley between prominent northwest-southeast trending ridges in the Northern Mount Lofty Ranges. The ranges are composed of a series of folded and faulted Late Precambrian sediments of Adelaidean age (700-600 million years ago) which were uplifted after the Tertiary (about 2 million years ago). The sedimentary succession is 15 000 m thick but copper mineralisation is restricted to units within the Skillogalee Dolomite, a 2 000 m thick series of dolomite and shale which lies towards the bottom of the sedimentary pile. The copper mineralisation in the Burra deposit is confined between two easterly dipping and northwesterly trending faults, Kingston and Tinline (Dickinson, 1942; Johnson, 1963).

Primary copper mineralisation was thought to be associated with the intrusion of a feldspar porphyry in the early Palaeozoic (500 million years ago; Nixon *et al.*, 1965). Drexel and McCallum (1986) interpreted volcanic activity (including the feldspar porphyry) to have formed the orebody, but more recently, during the Silurian-Carboniferous (420-350 million years ago) or younger. The original disseminated sulphide ore, of chalcopyrite, bornite and pyrite, has undergone extensive oxidation and secondary enrichment, and only very minor traces of these primary sulphides have been found in the lower parts of the mine workings. Prior to mining, the orebody was up to 70 m wide, 400 m long and extended to a depth of 100 m. It consisted of masses of banded malachite and azurite with minor amounts of cuprite, native copper, chrysocolla and libethenite. The host rocks were dolomite breccia, kaolinised shale and siltstone. The majority of ore occurred in dolomite breccia, the remainder as veins, blebs and nodules in intact host rocks.

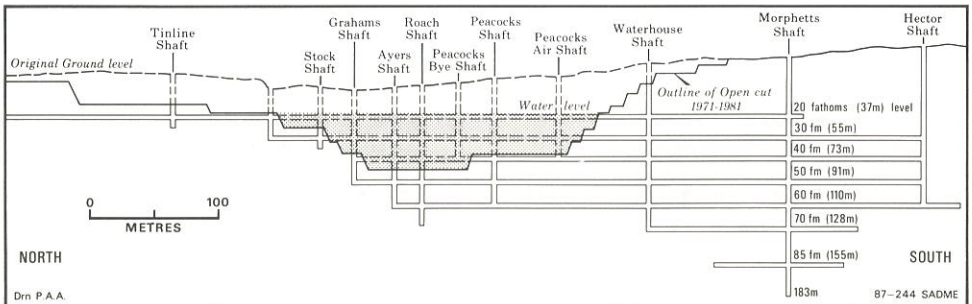


Figure 6. Longitudinal cross-section of the Burra Mine showing the extent of workings.

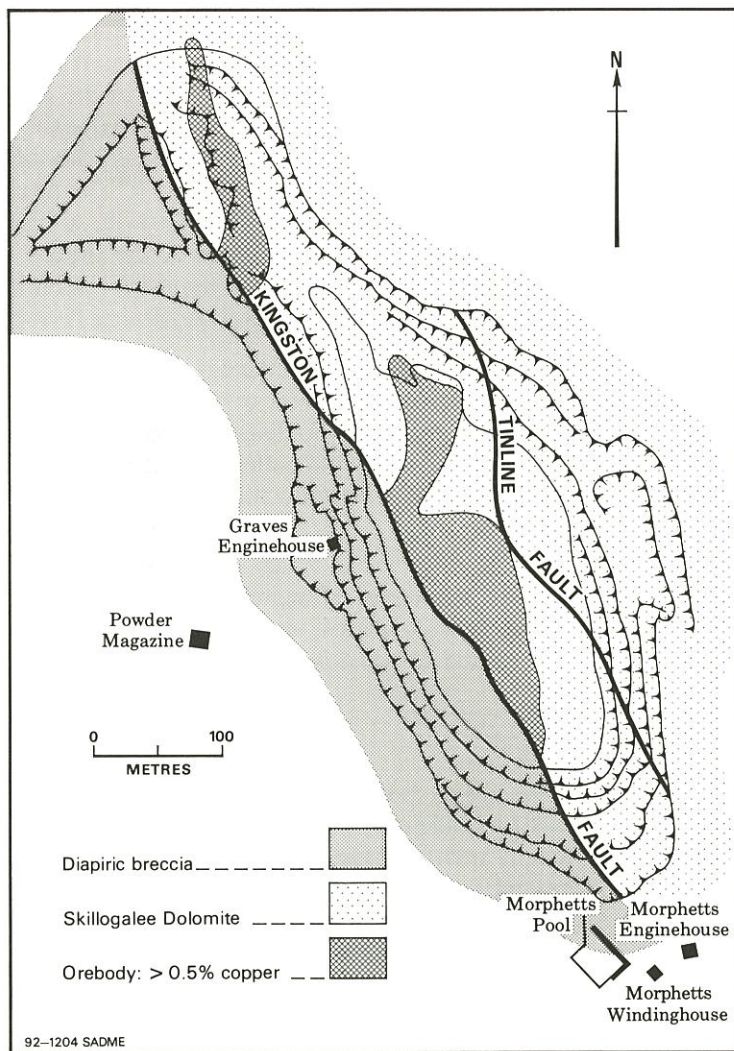


Figure 7. Geological map of the Burra orebody. The orebody is confined between Tinline and Kingston Faults.

THE MINERALS

The mineralogy of the Burra orebody is dominated by secondary copper minerals, particularly the copper carbonates malachite and azurite. Specimens of exceptional quality were found both during the early period of mining and in the 1970s. In the last century, fine mamillary malachite was found in considerable abundance and was in great demand as a gemstone. Specimens from Burra were displayed at most of the great exhibitions of the second half of the 19th Century. The South Australian Museum has a large mass of azurite and malachite which was shown at the Philadelphia Exhibition in 1878. A mass of 156 lbs of the finest malachite was sold at auction in Adelaide in November 1857. The prices realised for individual specimens were from 3 to 53 shillings per lb, a high price in comparison to a miner's weekly wage of 40 shillings at the time. The South Australian Museum has a fine collection of Burra material, including several collections presented by directors of the South Australian Mining Association.

A full list of the minerals reported from the Burra Mine is presented in Table 1. The more important minerals from a collector's point of view are described in detail below. The Burra Mine site today is an historic reserve and collecting is no longer permitted. However, Burra specimens from old collections do appear on the market from time to time and are eagerly sought by collectors.

Aragonite CaCO_3

Aragonite was found as crystalline masses of white to pale oily green colour with an internal radiating structure. These masses, up to 30 mm across, are associated with malachite and are penetrated by randomly orientated, rod-like columns of limonite.

Atacamite $\text{Cu}_2\text{Cl}(\text{OH})_3$

Atacamite was a scarce mineral at Burra. It occurred as dark green, flattened crystalline nodules to 40 mm on sandstone, and also as earthy crusts and black-green crystals to 1 mm lining vughy quartz. Many of the large, fine atacamite crystals labelled Burra, South Australia, and found in old collections almost certainly originated from the Moonta-Wallaroo district 90 km to the west (Pring, 1988). Atacamite crystals larger than 5 mm do not appear to have occurred at the Burra Mine.

Azurite $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$

Azurite occurred abundantly throughout the mine and was an important ore mineral. The mine yielded spectacular crystallised examples of this species, with some showing several different crystal habits on the one specimen. Azurite crystals up to 50 mm long have been found and are typically royal-blue to blue-black in colour, with a vitreous lustre. The most common habit is as translucent, flat blades in divergent sheaf-like clusters to 30 mm (but more commonly less than 15 mm)

scattered across botryoidal malachite, pseudomalachite, or turquoise-blue chrysocolla. Specimens with the latter association are particularly attractive due to the striking contrast in colour between the two blue minerals. Possibly some of the finest Burra specimens are spherical aggregates and rosettes of lustrous, platy azurite crystals. These are up to 50 mm in diameter and are typically perched on a matrix of impure chrysocolla, or tenorite-coated malachite.

It is the microcrystals of azurite from the mine, however, which show the greatest diversity in habit and generally the almost perfect development of form. Sharp, blocky to pseudocubic crystals occur to 3 mm; of rarer occurrence are equant crystals to 1 mm showing two periods of growth. The hollow centres of azurite nodules have been found lined with brilliant tabular or acicular crystals to 1 mm. These spherical nodules are up to 120 mm in diameter and occurred abundantly in a soft claystone. Their surface is typically made up of the terminations of small, bladed azurite crystals in some cases partially altered to chrysocolla. The first recorded occurrence of an azurite pseudomorph after libethenite was described by Peisley (1980) from material found in the open cut.

Barite BaSO₄

Sharp, lustrous crystals of barite up to 20 mm typically formed with azurite, malachite and libethenite on a chrysocolla or quartzite matrix. The crystals, of a bladed to tabular habit, are transparent and range in colour from colourless to pale yellow. Barite was also found as fawn-brown nodules to 70 mm across, the centres of which were vughy and lined with minute colourless barite crystals and occasional hemispheres of malachite.

Calcite CaCO₃

Calcite was a common and widespread mineral in the Skillogalee Dolomite which hosted the Burra orebody. The calcite occurs as white to pale brown grains up to 3 mm in diameter, and as dog-tooth and rhomb-shaped crystals to 3 mm in length lining cavities in the dolomite.

Chalcocite Cu₂S

Pseudomorphs and partial pseudomorphs of chalcocite after pyrite crystals (pyritohedra and less commonly octahedra) were relatively common in the kaolinised feldspar porphyry at the base of the open cut. The crystals, both individuals and clusters, are embedded in the kaolinite and have a lustrous iron-black colour. Individuals commonly reach 10 mm (very rarely greater than 40 mm) and faces are typically heavily striated. In most cases, the alteration to chalcocite has not proceeded very far, the chalcocite being only a thin, black coating on the pyrite crystals. Some crystals and aggregates are microfractured, the fractures having filled with earthy turquoise-blue chrysocolla which also partially encrusts the outside surfaces of the crystals giving them a dull lustre.

Chrysocolla $(\text{Cu,Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$

Chrysocolla was common at the Burra Mine and occurred in a range of colours: powder-blue, deep turquoise-blue, blue-green and olive-green, and in a variety of forms: powdery coatings, glassy to waxy botryoidal masses, and cryptocrystalline encrustations. It was present in the mine as veins and breccia fillings in quartzite and in malachite, and also as globular columns to 30 mm associated with platy azurite crystals. Concentrically banded malachite and chrysocolla intergrowths were also found. Bywater (1984a) reported chrysocolla occurring as translucent vugh fillings. Bywater (1984a,b) also described chrysocolla pseudomorphs after azurite, cuprite, copper and libethenite. The range of pseudomorphs indicates that chrysocolla is a generally late-forming mineral at Burra.

Copper Cu

Native copper was an important ore mineral during the early period of mining. It occurred in large masses associated with cuprite and the copper carbonates, and in some cases comprised a considerable proportion of the lodes. Typically it occurred in very crudely crystalline masses with a patina of malachite and cuprite. Occasionally, arborescent groups of sharp, elongated octahedra occur with individual crystals to 10 mm. Peisley (1989) reported native copper occurring as thin foliae in kaolinitic material.

Cuprite Cu_2O

Cuprite, like native copper, was a major ore mineral in the upper oxidised zones, and early reports mention masses of pure 'red oxide' weighing 500 pounds, and one upwards of a ton (Auhl, 1986). Cuprite was generally present as massive, reddish grey vein fillings associated with malachite and less commonly azurite. Free-growing crystals occurred where such veins opened into cavities. Cuprite crystals are generally sharp, gunmetal-grey octahedra with deep red internal reflections, elongated cubo-octahedra, or combinations of the octahedron and the dodecahedron. The crystals, to 20 mm, are frequently partly altered to velvety, green malachite. Of much rarer occurrence is the bright red acicular variety 'chalcotrichite' which was found in kaolinite.

Dolomite $\text{MgCa}(\text{CO}_3)_2$

Pale brown to beige dolomite is the dominant mineral in the Skillogee Dolomite. Cleavage masses of beige dolomite up to 100 mm diameter occurred throughout the orebody.

Fluorapatite $\text{Ca}_5(\text{PO}_4)_3\text{F}$

Prismatic crystals of fluorapatite up to 5 mm in length and ranging in colour from colourless through pale yellow to brown were found with libethenite and chrysocolla in the lower parts of the open cut. Fluorapatite was also found as brown, crystalline, botryoidal encrustations with libethenite.

Gold Au

Small amounts of gold occurred throughout the Burra orebody, but distinct specimens of native gold are rare. The South Australian Museum collection includes a small quartz specimen containing a 3 mm bleb of bright metallic native gold. The specimen was found during open-cut mining in the late 1970s.

Iodargyrite AgI

Modified tetrahedral crystals to 2 mm of iodargyrite in vughs in massive cuprite were found during open-cut mining. The pale yellow crystals occur with well-formed octahedral cuprite crystals up to 1 mm across, and with bladed malachite crystals up to 3 mm long.

Libethenite $\text{Cu}_2(\text{PO}_4)(\text{OH})$

Libethenite at Burra was uncommon in the earlier workings and only a few specimens containing the mineral are known from last century. In 1979, a libethenite-rich zone was located between the 430 and 480 m benches in the southern section of the open cut. The assemblage included libethenite, azurite, chrysocolla, pseudomalachite, fluorapatite and minor malachite (Bywater, 1984a). Within this zone sharp, lustrous crystals lining vughs in veins of massive libethenite were found in considerable abundance. Generally pseudo-octahedral in habit, the larger crystals reach 8 mm in length and are commonly elongated along their x-axis. Depending on their size, the crystals range in colour from deep green in crystals less than 0.5 mm to dark green-black in larger crystals. The majority of libethenite crystals from the mine are less than 2 mm across, and are commonly overgrown with turquoise-blue chrysocolla, the surface of which is frequently encrusted with large, lustrous azurite crystals. In some cases, larger libethenite crystals have orientated overgrowths of microcrystalline malachite on {011} faces only and, where {011} faces are not overgrown with malachite, they often show parallel growth steps (Noble, 1980). Hemispherical aggregates of libethenite microcrystals were also observed with a malachite alteration halo. Bywater (1984a) described libethenite pseudomorphed by azurite, chrysocolla and malachite.

Malachite $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$

The Burra Mine is well known as the classic locality for fine quality malachite. Most specimens seen in collections today were mined before 1877, but significant quantities were found by mineral collectors during the more recent mining activities. Although many thousands of tonnes of gem-quality malachite went to the smelter, enough was saved so that today thousands of specimens are still in circulation. The malachite occurred in the upper part of the oxidised zone in large masses and breccia fillings, commonly of gem quality, and was the main ore mineral at the mine. Of all minerals at Burra, malachite shows the most diversity of habit. By far the most common mode of occurrence is as radially compact, concentrically banded masses. Polished slabs of this material make spectacular specimens. It resembles malachite from the Shaba province of Zaire and the Ural Mountains of Russia.

Incomplete filling of cavities with this form of malachite resulted in the botryoidal/mamillary vugh linings for which Burra is famous. An attractive feature is that the botryoidal surfaces often have a high natural polish, and are occasionally encrusted with druses of lustrous, blue azurite crystals. Less common are columns with botryoidal surfaces, or botryoidal masses of more fibrous malachite. Unusual masses of honeycombed, cellular malachite may have formed by partial dissolution of more compact material. Crystallised malachite is by no means rare, though non-pseudomorphic crystals rarely exceed 10 mm in length. Radially acicular crystals to 10 mm line cavities in massive malachite. Bywater (1984b) described malachite of the same habit forming 'bowties' to 4 mm in association with leached crystals of azurite. Tabular crystals of an emerald-green colour, commonly 'v-shaped', occur to 5 mm on massive cuprite, or with libethenite and chrysocolla. Lustrous emerald-green 'arrowheads' of malachite occur to 4 mm, commonly encrusting botryoidal malachite. Malachite also occurs as unusual pseudo-cubic crystals to 10 mm in quartz, commonly with parallel growth on {001}. Pseudomorphic crystals of malachite after azurite are relatively common as druses with individuals to 30 mm, and are frequently associated with unaltered azurite crystals. These pseudomorphs occur in two main habits; as blocky prisms, and as delicate disc-like plates. Spherical nodules of earthy malachite are also common and reach 100 mm in diameter. They frequently have a knobby surface and in some cases a core of residual azurite.

Pseudomalachite $\text{Cu}_5(\text{PO}_4)_2(\text{OH})_4$

Pseudomalachite was reasonably common throughout the deposit, but its presence was often overlooked due to its similar appearance to the more abundant malachite. It occurred in banded, botryoidal encrustations of a deep-green to blue-green colour usually closely associated with malachite of a similar habit and often overgrown with chrysocolla, libethenite, or large crystals of azurite. Thin grass-green coatings of pseudomalachite occurred on fracture planes in massive quartz. Bywater (1984a) reported it occurring as transparent apple-green plates to 5 mm on chrysocolla from the 'libethenite zone'. Pseudomalachite has also been observed as rare pseudomorphs after libethenite.

Pyrite FeS_2

Pyrite of diagenetic origin was common in the mine and the surrounding area, and pyrite intergrown with chalcopyrite and closely associated with bornite constituted the primary sulphide ore. Apart from pyrite crystals partially altered to chalcocite, no other specimen quality material is known to have occurred.

Quartz SiO_2

Quartz was common in the mine and occurred in a variety of forms and colours. Large, sharp, colourless to pale smoky crystals up to 100 mm long and 35 mm wide occurred with a satin surface finish and hosted tufts and crusts of micro-acicular malachite. Druses of matt-black morion crystals occurred, with individuals to 30 mm across and with very little development of the prism faces. These druses were partially encrusted with small hemispheres and films of olive-green malachite. Chalcedonic quartz occurs in three habits: as white spherules to 6 mm with microcrystalline malachite lining vughs in concretionary limonite; as grey-blue columns to 50 mm, the surfaces of which are covered with minute quartz crystals (in massive quartz vughs); and as dark blue encrustation pseudomorphs after azurite crystals to 2 mm. Peisley (1989) reported quartz occurring as sherry-red crystals to 1 mm and as sceptres to 2 mm in calcite.

Table 1. Minerals identified from the Burra Mine, South Australia

NATIVE ELEMENTS

copper	Cu
gold	Au

SULPHIDES and SELENITES

bornite	Cu_5FeS_4
chalcopyrite	CuFeS_2
covellite	CuS
chalcocite	Cu_2S
digenite	Cu_9S_5
pyrite	FeS_2

OXIDES and HYDROXIDES

cryptomelane	$\text{K}(\text{Mn}^{4+}, \text{Mn}^{2+})_8\text{O}_{16}$
cuprite	Cu_2O
goethite	$\text{FeO}(\text{OH})$
haematite	Fe_2O_3
opal	$\text{SiO}_2 \cdot n\text{H}_2\text{O}$
pyrolusite	MnO_2
quartz	SiO_2
tenorite	CuO

HALIDES

atacamite	$\text{Cu}_2\text{Cl}(\text{OH})_3$
iodargyrite	AgI

CARBONATES

aragonite	CaCO_3
azurite	$\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$
calcite	CaCO_3
dolomite	$\text{MgCa}(\text{CO}_3)_2$
malachite	$\text{Cu}_2(\text{CO}_3)(\text{OH})_2$
siderite	FeCO_3

PHOSPHATES

fluorapatite	$\text{Ca}_5(\text{PO}_4)_3\text{F}$
libethenite	$\text{Cu}_2(\text{PO}_4)(\text{OH})$
pseudomalachite	$\text{Cu}_5(\text{PO}_4)_2(\text{OH})_4$

SULPHATES

barite	BaSO_4
brochantite	$\text{Cu}_4(\text{SO}_4)(\text{OH})_6$
chalcantithite	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
jarosite	$\text{KFe}_3(\text{SO}_4)_2(\text{OH})_6$

SILICATES

chrysocolla	$(\text{Cu}, \text{Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$
halloysite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$
kaolinite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$
nontronite	$\text{NaO} \cdot 3\text{Fe}_2(\text{Si}, \text{Al})_4\text{O}_{10}(\text{OH})_2 \cdot n\text{H}_2\text{O}$
orthoclase	KAlSi_3O_8
tremolite	$\text{Ca}_2(\text{Mg}, \text{Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$



*View of open-cut mining in 1980, with Morphetts Enginehouse in the background.
(Photo no. 42372)*



*Morphetts Enginehouse after its reconstruction in 1986, with Morphetts
Windinghouse in the background. (Photo no. 37803)*

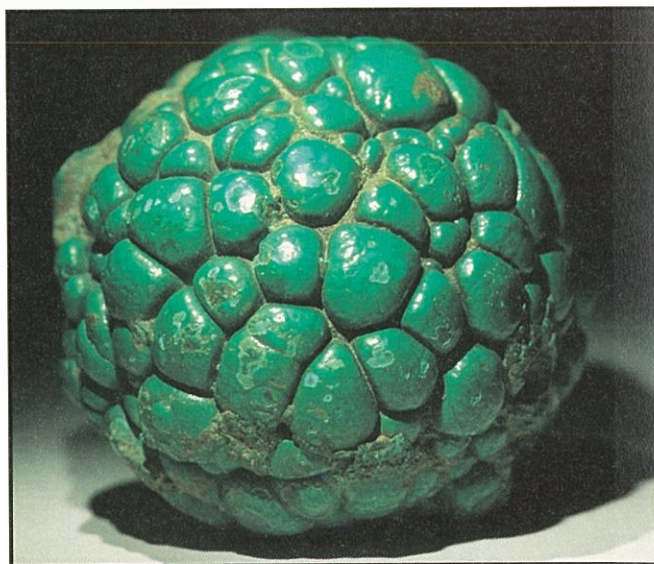


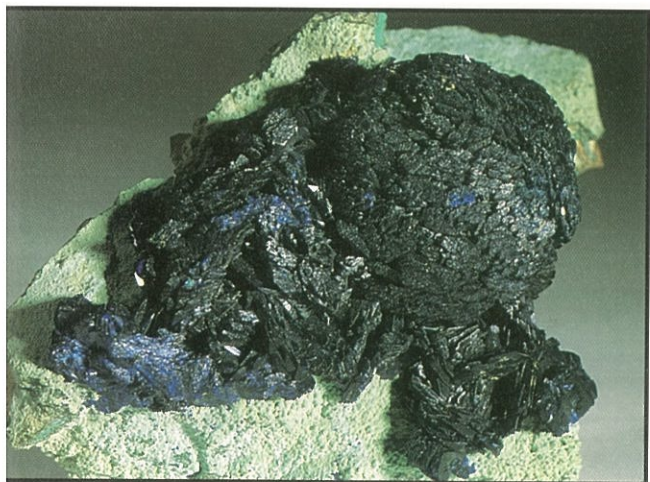
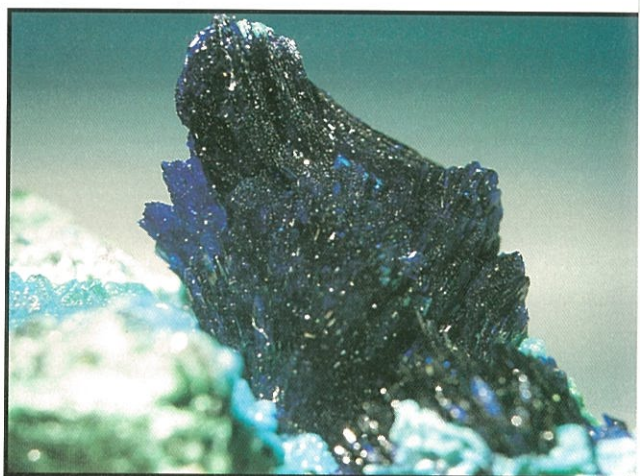
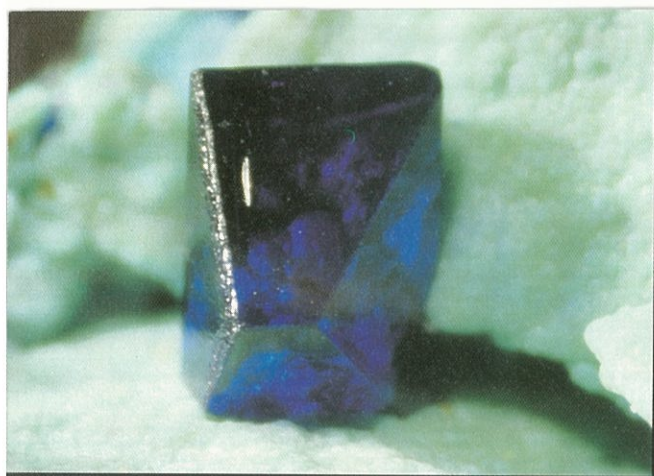
Botryoidal malachite on matrix, 120 mm in diameter. This specimen was presented to the South Australian Museum by Sir Henry Ayers in 1881. (Photo no. 42373)

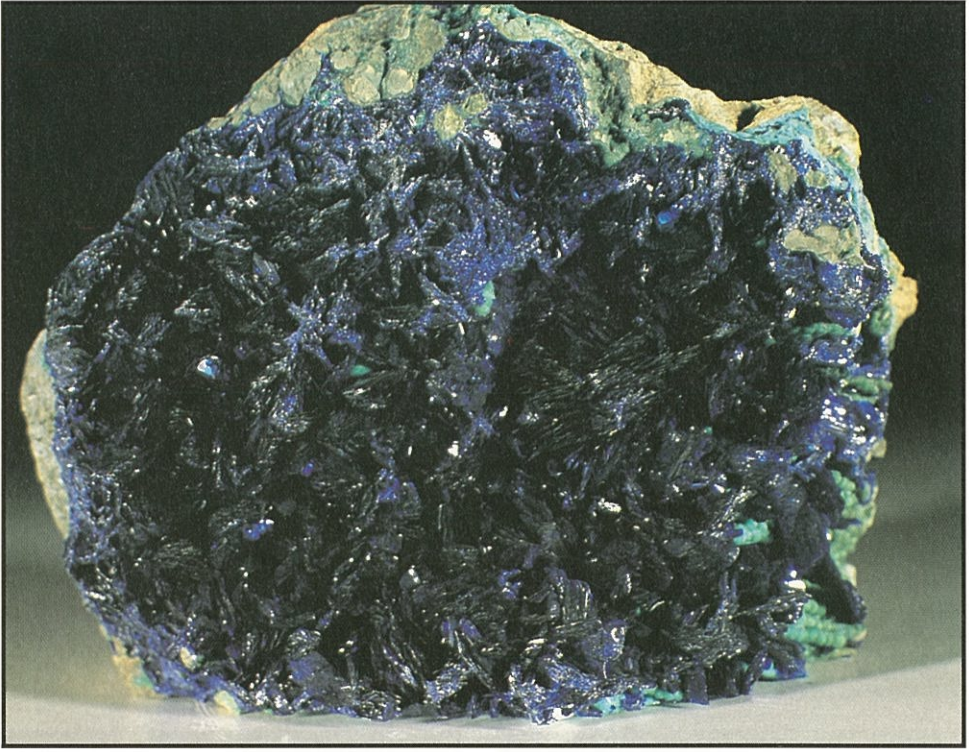
TOP: Pseudomorph of malachite after azurite. The blade-like crystals are 2 mm long. (Photo no. 42374)

MIDDLE: Tuft of malachite crystals to 3 mm on quartzite. (Photo no. 23618)

BOTTOM: Botryoidal mass of malachite 50 mm in diameter. (Photo no. 42375)







Blade-like azurite crystals to 15 mm on botryoidal chrysocolla. This 110 by 90 mm specimen was presented to the South Australian Museum by Sir Henry Ayers in 1881. (Photo no. 42379)

TOP: Blocky, 2 mm azurite crystal on botryoidal chrysocolla. (Photo no. 42376)

MIDDLE: Intergrown group of bladed azurite crystals 20 mm long on botryoidal chrysocolla. (Photo no. 42377)

BOTTOM: Group of blue-black azurite rosettes on pale bluish green chrysocolla. The specimen is 100 mm across. (Photo no. 42378)



TOP: Atacamite nodule on sandstone. The nodule is 45 mm across. (Photo no. 42380)

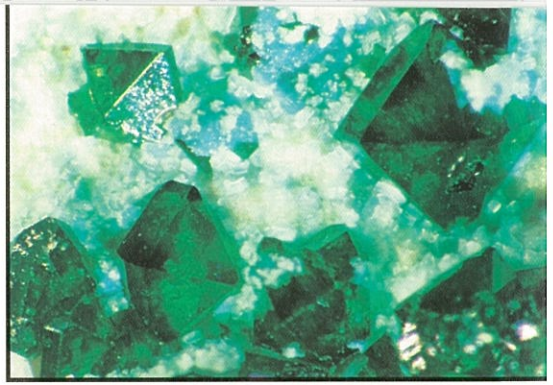
MIDDLE: Pale yellow, 5 mm barite crystals on pale blue chrysocolla. (Photo no. 42381)

BOTTOM: Chrysocolla after azurite. The pale blue pseudomorphed crystals are 2 mm long. (Photo no. 42382)

TOP: Chalcocite after pyrite. The larger crystal is 10 mm across. (Photo no. 42383)

MIDDLE: Mass of crude copper crystals to 0.3 mm diameter. (Photo no. 42384)

BOTTOM: Cuprite on matrix. The cubic crystals are 1 mm on edge. (Photo no. 42385)



TOP: Octahedral cuprite on matrix. The crystal is 2 mm on edge. (Photo no. 42386)

MIDDLE: Gold on massive white quartz. The bleb of gold is 3 mm in diameter. (Photo no. 42387)

BOTTOM: Pale yellow iodargyrite with deep red cuprite. The tetrahedral iodargyrite crystal is 1 mm on edge. (Photo no. 42388)

TOP: Libethenite on botryoidal chrysocolla. The largest crystal is 0.5 mm on edge. (Photo no. 23615)

MIDDLE: Libethenite on quartz. The crystal is 0.5 mm on edge. (Photo no. 42389)

BOTTOM: Group of pale smoky quartz crystals with minor malachite. The crystal at left is 27 mm across. (Photo no. 42390)

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REFERENCES

- Auhl, I., 1986. *The story of the 'monster mine'. The Burra Mine and its townships 1845-1877*. Investigator Press, Adelaide.
- Birch, W.D., 1987. Gold in Australia. *Mineralogical Record*, 18:5-32.
- Bywater, S.K.G., 1984a. The libethenite zone, Burra Mine, South Australia. *Mineralogical Record*, 15:105-108.
- Bywater, S.K.G., 1984b. Pseudomorphs from the Burra Mine, South Australia. *Mineralogical Record*, 15:219-222.
- Drexel, J.F. and McCallum, W.S., 1986. The origin and age of the Burra copper orebody. *South Australia. Geological Survey. Quarterly Geological Notes*, 98.
- Dickinson, S.B., 1942. The structural control of ore deposition in some South Australian copper fields, No. 1. *South Australia. Geological Survey. Bulletin*, 20:66-78.
- Drew, G.J., 1987. *Morphetts Enginehouse and the Cornish Beam Engine, Burra Mine, South Australia*. The Burra Mine Management Committee, Burra.
- Drew, G.J., 1988. *Discovering historic Burra, South Australia*. South Australia Department of Mines and Energy, Adelaide.
- Johnson, W., 1963. A reinterpretation of the Burra copper deposit. *Australasian Institute of Mining and Metallurgy. Proceedings*, 206:63-91.
- Nixon, L.G.B., Fairburn, W.A. and Warne, K.R., 1965. Progress report No. 1 — Burra Mines investigation. *South Australia. Department of Mines. Report Book*, 61/47.
- Noble, R.J., 1980. Libethenite at the Burra Copper mine. *South Australia. Geological Survey. Quarterly Geological Notes*, 76:2-5.
- Peisley, V., 1980. Rare minerals from Burra. *Australian Gem and Treasure Hunter*, 49:38.
- Peisley, V., 1989. Burra copper mine, South Australia. *Mineralogical Society of South Australia — Mineralogical News*, 9.
- Pring, A., 1988. Minerals of the Moonta and Wallaroo mining districts, South Australia. *Mineralogical Record*, 19:407-416.

