Mercury Mining: A Quick History of Quicksilver in Australia

By KEN MCQUEEN
University of Canberra

Mercury is one of the few metals not produced in significant quantity in Australia. In the nineteenth century this was an important deficiency as mercury was crucial in the production of gold. Until the development of the chlorination and cyanidation processes, mercury amalgamation was the main method of extracting gold (and silver) from quartz reef and lode deposits. Mercury was also used to catch very fine gold during alluvial mining. Even after more efficient gold extraction processes were developed in the late nineteenth century, amalgamation was still widely applied in the Australian gold industry. For example, in 1938 Australia imported over 76 thousand pounds (34.7 tonnes) of mercury, mostly for gold processing.[1] The high gold price in recent decades has driven a demand for mercury by artisanal gold miners, mainly in third world countries.

Mercury, or quicksilver, has had many other uses including in the electrical industry for switches, in measuring instruments such as thermometers and barometers, in dental amalgam, as a pigment in the form of the sulphide and as mercury compounds used in preparing felt hats, and in medicine and pharmaceuticals, utilising its antibacterial properties, including as an early treatment for syphilis. Until the second half of the twentieth century mercury fulminate was widely used in primers and detonators for ammunition and high explosives, making it a strategic element during times of war. Its main modern usage has been in mercury cells for the production of chlorine and caustic soda by the Castner-Kellner process and as mercury vapour in low-energy fluorescent lighting. Many historic applications have been, or are being phased out because of the high toxicity of mercury and its detrimental effects on the environment and human health. In global resource terms, mercury is an example of a commodity for which the supply is predicted to significantly overtake a declining demand over at least the next several decades.[2]

The principal ore mineral of mercury is cinnabar, the vermilion coloured sulphide. It also occurs more rarely as native mercury and in a range of amalgams with other metals, as well as a constituent in minerals such as coloradoite (mercury telluride) and mercury-bearing sulphosalts. Most production has been from primary cinnabar deposits, but significant amounts are produced as a byproduct of gold, silver and some base metal mining. Some mercury is produced from natural gas refining. Total world production in 2007 was estimated at 1,170 tonnes, with the major producers being China and Kyrgyzstan.[3] Historically, deposits at Almaden in Spain, Idria in Slovenia, New Almaden and New Idria in California and Huancavelica in Peru have been major producers.

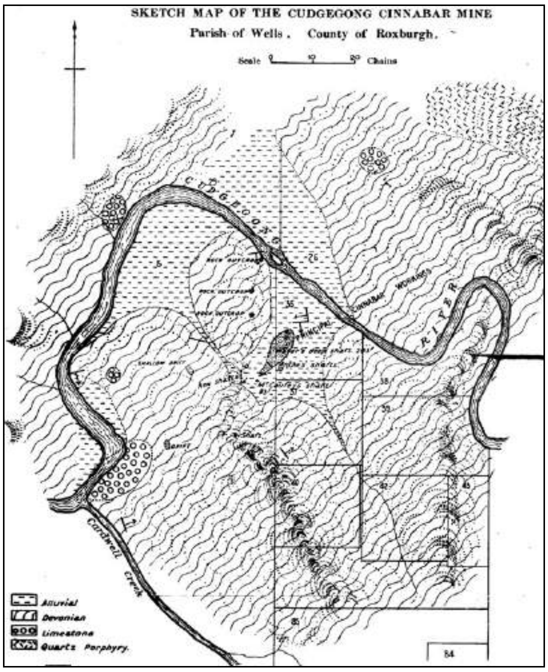
Between 1869 and 1945 attempts were made to mine mercury occurrences in Australia, with varying but limited degrees of success. The largest production (15.2 tonnes) was from the Kilkivan district in southeast Queensland, but in global terms, total production was insignificant. This miniscule production was despite the high local demand for the metal and the wide range of geological environments in Australia that might host mercury deposits.

Earliest discoveries of mercury in Australia

The first discovery of mercury in Australia appears to have been in 1843 near the Cudgegong River, 7 km west of Rylestone in central New South Wales (Figure 1). In 1857 the Reverend W.B. Clarke reported that in 1843-4 he received a sample of yellow soil from the Mudgee area containing several minute globules of quicksilver.[4] At the time Clarke was sceptical of the discovery, suspecting the mercury may have spilt from some explorer's barometer. Later, in 1875, after cinnabar had been found near Cardwell Creek, Clarke wrote that 'about 1841 I received the first sample of quicksilver from the neighbourhood of the locality on Carwell (sic) Creek on the Cudgegong River, where the cinnabar was found'.[5]

Figure 1: *Location of the main Australian mercury occurrences in this article.*

Figure 2: *The Cudgegong cinnabar deposit west of Rylestone, NSW.*



Source Figure 2: J.E.Carne, '*Mercury or "Quicksilver" ', in New South Wales, Minerals Resources No. 7* (2nd Edn), New South Wales Department of Mines, Geological Survey, 1913.

In October 1851, Samuel Stutchbury, Geological Surveyor to the Colonial Secretary, commented on the reported discovery of amalgam and mercury in the Ophir area and at Mookerawa Creek. He supposed that the mercury and amalgam at the first locality might have escaped from some amalgamating machine during alluvial gold mining, but concluded that this could not have been the case at Mookerawa Creek, where no quicksilver had yet been used.[6]

The first documented discovery of cinnabar was made in 1868 near the Cudgegong River (Figure 2).[7] Gold miners working high level gravels had noticed fine, heavy red material in their dishes and a sample was sent to Mr S.L. Bensusan for testing in his Sydney laboratory. This proved to be cinnabar, but the prospector who had submitted the sample, Peter Dickson, apparently discredited the determination. Mr Bensusan then sent an agent to locate the source of the sample and after purchasing the land, visited the site to organise prospecting operations. A rich patch of cinnabar-bearing gravel was soon struck in a shaft at 14 feet and found to extend to a depth of about 50 feet. In early 1869 a bulk sample (5cwt) was sent to Sydney for testing.[8] Some of this sample was retorted with great interest at the Barcom Glen Ice Works near Paddington by a well-known and experienced analytical chemist, Mr Charles Watt, using an Ure's ordinary gas retort. A number of luminaries were present at the experiment, notably the Hon. S. Samuel (Colonial Treasurer), Hon. John Sutherland (Minister for Works), Mr Mathew Goggs of Queensland and Captain W.H. Eldred, together with other spectators including two Chinese observers.[9] From 105 pounds of cinnabar ore, 49 pounds of mercury were produced.

Following this successful testing, the Cudgegong Cinnabar Mining Company was formed with a capital of £30,000 in £1 shares. The company expended about £10,000 on surface works including a bank of three Ure's retorts, condensing chamber, chimneystack, a wet concentrating plant and sheds. Up to eight miners had already developed the deposit in several shafts, which had intersected good ore at a depth of about 42 feet associated with a yellow clay layer. At the second half yearly meeting of the company in January 1870, it was reported by the manager, Mr Grainge, that 60 tons of cinnabar ore had been raised during the year. Attempts were made to concentrate some of the lower grade material by loose grinding and washing in puddlers, but it was found that much of the fine-grained cinnabar was lost resulting in no effective concentration.[10] Overall the results of the operation were disappointing with only about six flasks (456 lbs) of mercury produced from a considerable amount of cinnabar-bearing sand and gravel.

The cinnabar at Cudgegong appears to have been an alluvial deposit in an old river channel with associated alluvial gold and also some gold amalgam. In 1884, Geological Surveyor C.S. Wilkinson who reported evidence of extensive abandoned workings visited the site. He recorded comments from a Mr Watson who had been involved in the mining, indicating that cinnabar had been found in the drift down to a false bottom at about 40-50 feet from the surface. However, no cinnabar had been found below this level, down to bedrock at about 117 feet.[11] Some of the cinnabar occurred as coarse lumps (essentially cinnabar 'nuggets') with several from 1 to 10 ozs and the largest up to 2.5 pounds. Wilkinson noted much of the cinnabar was well rounded, some pieces were angular and some solid cinnabar appeared to merge into or impregnate the drift material. There was much fine-grained cinnabar dispersed in the matrix of the gravel. Curiously, he suggested that the cinnabar may have been deposited from hot spring activity but noted no indication of such a process that might also have been expected to deposit siliceous sinter.[12] Recent observations by the present author revealed the gravels to be very oxidised and ferruginous, indicating conditions insufficiently reducing to allow precipitation of sulphide minerals like cinnabar from solution. Cinnabar is one of the few sulphide minerals that are chemically stable under surface weathering conditions and it is commonly found as a placer mineral in alluvial deposits. The early miners clearly understood the deposit as an alluvial lead and attempted to locate the primary source of the cinnabar, both by driving up the channel and sinking into the bedrock below it down to 202 feet.[13] This search was unsuccessful. Subsequently an Adelaide syndicate attempted to trace the source by cutting a costean and sinking two shafts up the ridge from the deposit.[14] No trace of cinnabar was found and the primary source **is** still unknown.

Discoveries and mining at Kilkivan

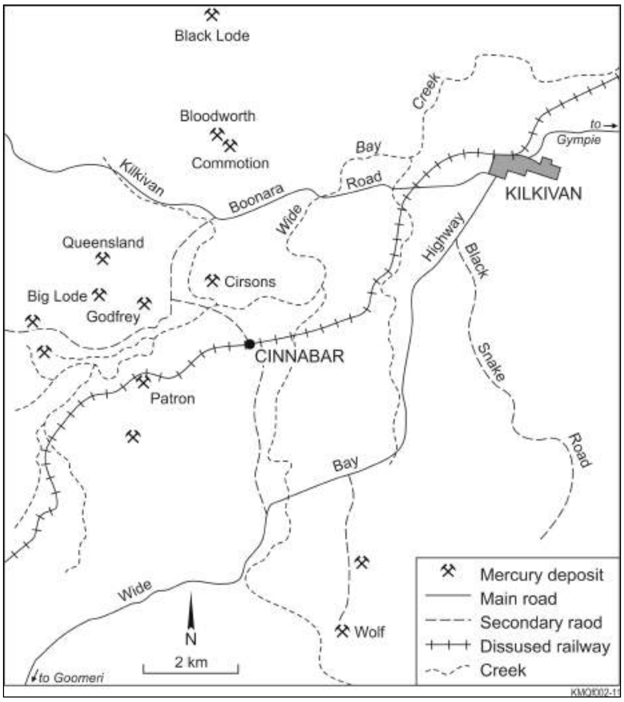
In 1872 Edward Godfrey, a shepherd on the sheep run of J.D. Mactaggart at Kilkivan in southeast Queensland (Figure 1) found heavy, dark red stones that were identified as cinnabar.[15] Samples were sent for analysis and revealed 24.05 per cent mercury with some associated copper selenide.[16] Dan Mactaggart (nephew of J.D. Mactaggart), Fane and Bray, took out a lease of about 240 acres, while the Wide Bay and Gympie Cinnabar Company selected several other leases in the area. Samuel L. Hester and his brother William, experienced miners who had worked in the mercury mines of California, together with Captain W.H. Eldred took control of the operations on these leases.

Meanwhile, other prospectors located further outcrops of cinnabar and near the end of 1873, Dr Gustav Wolff, a geologist representing an Austrian syndicate, came over from California with the aim of obtaining the best of the deposits. He purchased one of the claims (Coop's find, subsequently renamed the Wolf mine, see Figure 3) and obtained a proposition from Mactaggart and company for the sale of their claims.[17] These latter claims were never purchased because Wolff died on his journey back to Austria and the negotiations fell through.[18]

By 1873 the public was wary of speculative mining ventures due to the collapse of the recent tin and copper 'mania' booms[19] and the quicksilver syndicates were unable to attract capital to properly develop their deposits. The Hester brothers patiently acquired the various claims as they were abandoned and once they had secured most of the field, set up a retorting furnace.[20] Their primitive treatment plant gave encouraging results on the first batch of ore and by May 1874 they had produced one hundredweight (50.8 kg) of mercury.[21] To this point they had expended over £1,000 of their own capital, but were still unable to attract additional investment. They persisted until 1876 using their own resources and were able to produce a total of two tons (2,032 kg) of mercury from about 50 tons of high-grade ore, which they sold to the gold mines in Gympie and the nearby Rise and Shine mine in Kilkivan for gold processing. They also retorted small parcels of ore from the claims of Mactaggart and Bloodworth. The

Hesters then suspended operations until arrangements could be made to work the mines in a more efficient and profitable manner.[22]

Figure 3: *Map of the Kilkivan area showing the recorded cinnabar deposits and occurrences. There are also deposits of copper and gold closer to Kilkivan.*



Source: J.H. Brooks, J.N. Syvret and J.D. Sawers, *Mineral Resources of the Kilkivan district*, Report No 60, Geological Survey of Queensland, 1974.

In early 1881 the Duke of Manchester, William Drogo Montagu, visited Queensland with a view to investing in mining and pastoral properties.[23] During his extended stay he inspected the Kilkivan quicksilver field and collected samples to take back to London. He also arranged for additional samples to be sent from the mines to London for systematic assay.[24] Johnson, Matthey and Company, assayers to the Bank of England, reported that these samples contained up to 74 per cent mercury.[25] The Duke was persuaded to form a company to develop the field and in early 1886 the Queensland Quicksilver Estates Company was floated in London with a nominal capital of £400,000 in £1 shares, initially paid up to £60,000.[26] The directors were the Duke of Manchester, the Earl of Gosford, Col. G.M. Malleson, Captain W.H. Eldred, S. Hedges and C.W. Tancred.[27] The claims incorporated in the new company covered about 330 acres of freehold land and included the Queensland, Gully, Susan, Sligo, Patron, Old Man and Wolf.[28] The vendors, presumably the Hesters and partners Thomas Donaldson and Captain William Eldred, received 340,000 fully paid shares and £15,000 in cash for the property.[29] The Duke recorded that:

> From all they can learn of the richness of the property, the directors are satisfied that the Queensland quicksilver mines will be most profitable. Queensland and the Australian colonies alone furnish a market believed to be sufficient to ensure large dividends ... On the basis of only 1s 6d per lb, which is the lowest price

> ever known on the London market, the directors estimate that the company will be enabled to produce profits of at least 25 per cent upon the capital of the company.[30]

Operations commenced in July 1886 with exploratory work on various lodes and major development at the Queensland, Gully and Wolf deposits. By the end of 1887 the main shaft at the Wolf mine was down 240 feet and connected to an adit from the side of the hill. Internal workings consisted of drives and two winzes connected to an underlay shaft. At this mine about £5,000 had been spent on buildings and machinery. Temporary retorts (possibly those originally built by the Hesters) were reported to be in place.[31] In December 1887 the Duke of Manchester paid another visit to Kilkivan to inspect the company's operations and delegated James Hurst, geologist and mineralogist, to thoroughly inspect and report upon the various mines to ascertain the best approach to processing the ore. An artist-correspondent of the *Town and Country Journal* was despatched to inspect and describe the Kilkivan mineral field, including the cinnabar mines, and accompanied the Duke in his special train from Maryborough. He reported favourably on the occurrences, noting that some of 'the stone exposed to view is the finest cinnabar ore we have ever seen' and that assays 'show them to be second to none in the world'. He also drew and published several sketches of the workings.[32]

The glowing accounts and expressions of optimism were soon found to be premature. By September 1888 the company had expended £8,600 on development, £6,925 on preliminary expenses, rent, directors fees, salaries and general office expenses, but had produced only nine flasks of mercury (672 lb) worth £82 10s.[33] It seemed that the grades of ore had been greatly overestimated and the difficulty of efficiently extracting the mercury greatly underestimated. The earlier work by the Hester brothers had shown that the average grade of the best ore on the field was about 4 per cent mercury and that much larger volumes ran about 2.5 per cent. Given proper processing, the latter should still have paid well, as many cinnabar ores in California at or below this grade were profitably worked. Mismanagement, adverse publicity and some bad luck appear to have dogged the company. During 1888 legal issues arose between the Hesters and Captain Eldred over the nature of their former partnership.[34] James Hurst, the geologist, was committed for trial in Gympie on a charge of obtaining money under false pretences from Edward W. Bathurst, a Sydney speculator. The charge was dismissed, but the incident probably raised doubts about his probity.[35] On his trip back to London to report to the Duke of Manchester and other directors, Hurst perished in the wreck of the Quetta in Torres Straight on the 28th February 1890.[36] The Duke himself died of dysentery at Naples in March 1890.[37] With such difficulties and dismal results, the Queensland Quicksilver Estates Company soon came to grief and in September 1890 its Queensland assets were sold off.[38]

Following this debacle the Hester brothers again took over the leases and resumed activities on a modest scale producing 3,360 lbs of mercury in 1891. The mines were then let out on tribute for a short period and another 4,480 lbs were produced in 1892, before falling prices made such small scale exploitation unprofitable.[39]

Clarence River cinnabar

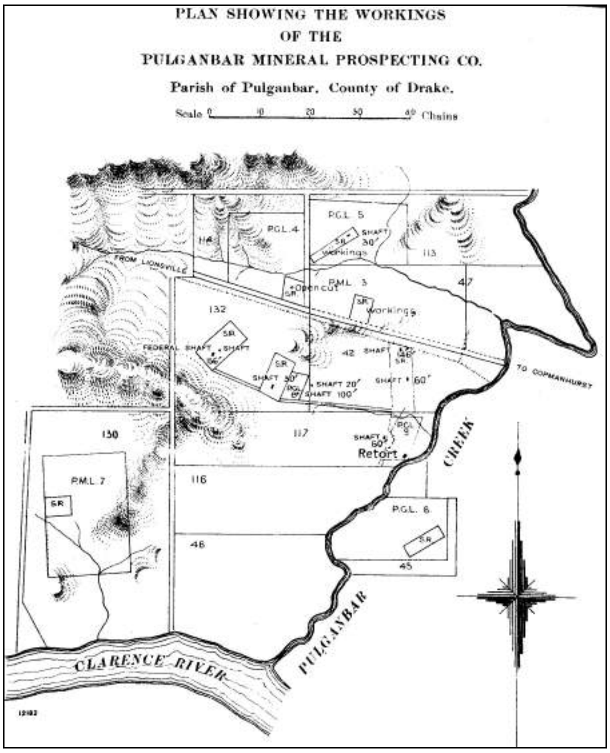
In December 1890 William Kelly, prospecting with his brother in an area of antimony and silver mineralisation, discovered cinnabar at Horseshoe Bend near the Clarence River in northern New South Wales.[40] Geological Surveyor T.W.E. David from the Geological Survey of New South Wales inspected the site the following March and described the occurrence as 'a dyke, 12 feet wide, of feldspathic rock, allied to serpentine containing cinnabar, distributed irregularly in spots and minute veins'. The dyke had intruded the local granite and David considered that it would extend to a considerable depth. He recommended that the prospectors be granted aid from the Prospecting Vote to extend their shaft, but this was not taken up.[41]

There was a more important discovery in 1895 about 16 miles (25 km) up river on Yugilbar station (Figure 1), when Laurence Fox picked up a loose surface specimen containing disseminated cinnabar. The occurrence was in altered granodiorite at the contact of an intrusive diorite dyke and in proximity to a large serpentinite body. By October two shafts had been sunk 50 and 20 feet on a distinct east-west trending vein, revealing narrow irregular veins up to several inches (7.5 cm) wide and with disseminations of cinnabar.[42] Geological Surveyor Joseph Carne examined the site and government aid was granted to the prospectors, Bassetti and party, to deepen the main shaft and sink another. They deepened the shaft to 95 feet, but the claim for the new proposed shaft was forfeited and taken up by Miller, Pollard and party. Two additional shallow shafts were sunk and an open excavation made on a new discovery by a group headed by a Dr Flateau. Then in August 1899 the Great Australian Quicksilver Mining Company was formed to acquire and systematically develop the Yugilbar deposits.[43] Development work in 1900 revealed some rich cinnabar specimens containing up to 75 per cent mercury.[44] Alexander Milne in conjunction with Dr J. Elliott from Elliott Brothers Limited, a company with chemical works at Balmain in Sydney, conducted a series of retorting experiments on parcels of ore.[45] Joseph Carne again visited and reported on the site and recommended that the company conduct further prospecting and detailed proving of the deposit before erecting a processing plant. This advice was ignored and the company promptly built a retort to process ore from the rather limited existing workings. The brief retorting program produced 1,120 lbs of mercury.[46]

Following a hiatus in activity, the Company proposed investing £1,000 to re-timber the main shaft and resume development. Work commenced in September 1901 and further experiments were conducted on lower grade ore. An improved furnace designed by Dr Elliott on the Excelsior Monitor principle and capable of treating up to 50 tons per week was erected in 1902. The plan was to treat lower grade ores on a larger scale to avoid the need for expensive ore dressing or concentration.[47] Processing commenced in 1903 with 40 tons of ore treated for a return of 1,010 lbs of mercury. At this point operations ceased and it seems that there was not even enough lower grade ore in the mine to supply the plant for more than a week or two.[48]

Twenty-four miles (38 km) to the south, near Pulganbar Creek on Gordon Brook station (Figures 1 and 4), copper ores had been discovered and intermittently worked since 1873. These deposits included the Glamorgan (previously Jakoombi) mine, Flintoff's lode, and the Federal lodes. About 1908, miner, Archie McLean, recognised cinnabar with the copper and cobalt minerals in some of the ore.[49] In November 1908 the Pulganbar Mineral Prospecting Company was floated with a nominal capital of £15,000 in £1 shares. This company was set up to consolidate the various holdings of the existing Pulganbar Syndicate, the Federal Syndicate and the New England Prospecting Company NL. Totalling 400 acres on the western side of Pulganbar Creek (Figure 4), it was intended that the cinnabar and copper ores on the holding should be systematically explored and developed. The vendors were allocated 5,000 shares and £1,500 in cash, with 10,000 shares offered to the public to provide working capital.[50]

Figure 4: *Map of the Pulganbar cinnabar workings in 1910.*



Source: J.E. Carne, '*Mercury or "Quicksilver" ', in New South Wales, Minerals Resources No. 7* (2nd edition), New South Wales Department of Mines, Geological Survey, 1913.

Development was focussed on the westernmost Federal lode where the main shaft and two levels revealed a fissure vein within granodiorite containing cinnabar and calcite, also with some copper and iron sulphides. This vein had a steep dip to the northwest and was up to 18 inches thick in the bottom of the main shaft. Very rich cinnabar occurred in two lenses 2 to 8 inches wide. Prospecting also revealed slugs of cinnabar in the overlying soil, extending down slope for 200 feet. Several other cinnabar-bearing lodes were identified further east at numbers 1, 2, 3, 4 and 5 shafts, with some high grade ore (ca. 10 per cent mercury) also associated with copper carbonates and ironstone.[51] About 300 tons of low-grade ore and 50 tons of high-grade ore were raised during 1911.[52] A small retort consisting of a hand-rotated cast-iron vessel and capable of treating one ton batches of ore was constructed on the west bank of Pulganbar Creek by the Manager D.H. Thomas, a metallurgist with experience in copper smelting. In August 1911 this experimental plant processed several tons of high-grade ore by heating with lime before the iron retort cracked from the effects of heating and cooling.[53]

Meanwhile, the Clarence Cu Co Mining Company Ltd, which held the area on the eastern side of Pulganbar Creek, had found cinnabar in some of their workings and in December 1911 it was agreed to merge the two groups into the Pulganbar Quicksilver and Copper Mining Company Ltd.[54] The new company, under the chairmanship of E.S. Francis, quickly set about further developing the lodes and constructing an elaborate reducing plant to process the mercury-copper ore on a large and continuous basis. The company located suitable clay deposits nearby and set up a brick works to supply bricks for the plant. They also built their own sawmill and constructed a bridge across Pulganbar Creek to connect the main mines with the plant that was to be built on the sloping eastern bank of the creek at a cost of £2000.[55]

In 1900 the New South Wales government had offered a reward of £500 to the first person or company to produce 50,000 pounds of mercury. The aim of the reward was to encourage prospecting for this key precious metal, as well as to stimulate the development of known deposits.[56] As no one had to that point claimed the reward, the Pulganbar Quicksilver and Copper Mining Company built this into their business plan.[57]

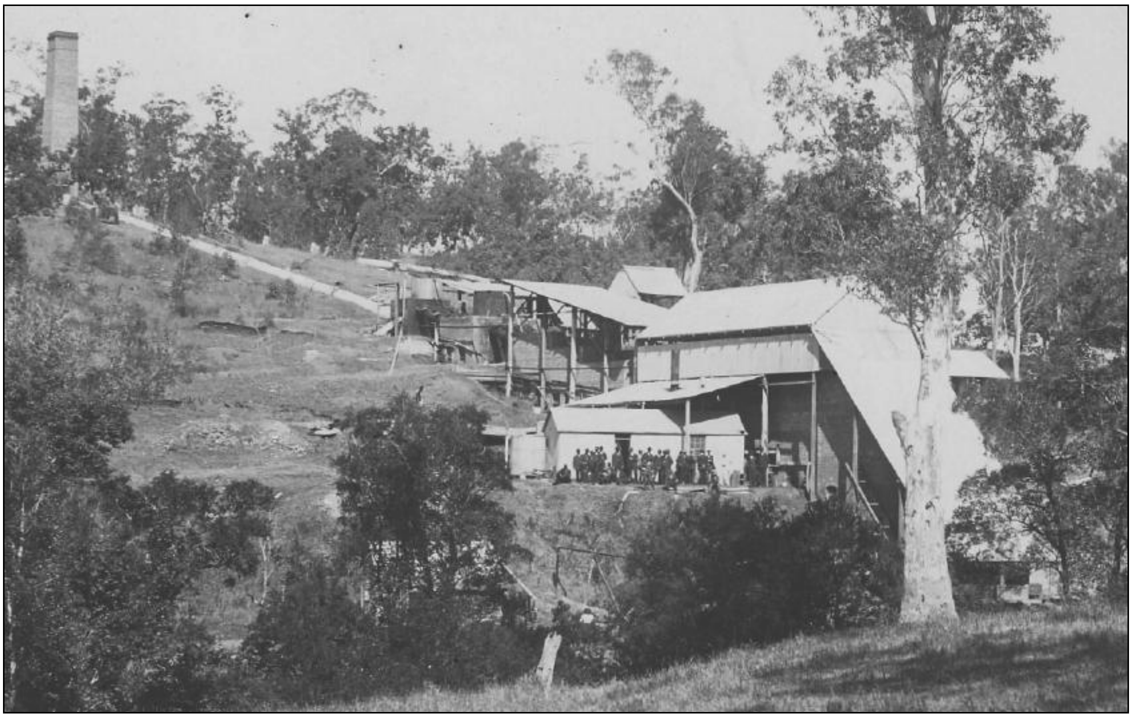
While excavations for the plant commenced in April 1912 and the concrete foundations were laid by July,[58] labour problems then arose at the brickworks, which delayed construction.[59] At the mines, work on the main Federal lode had extended the north drive on the 70-foot level to 97 feet and the south drive to 63 feet. Good ore up to 1.5 feet wide continued in the south drive and about 18 tons were stoped out by early May. Some of the high-grade ore on this level contained small globules of metallic mercury. The mine manager planned to develop a second level at the bottom of the shaft. Driving on high-grade ore also commenced on the 60-foot level in the No. 4 shaft.[60] By the end of 1912 about 2,000 tons of cinnabar-bearing ore was at grass awaiting completion of the new reducing works.[61]

Largely completed by early 1913, the reducing works were designed to treat 20 tons of ore per day and incorporated a crushing plant, water pumping system with reservoir and a continuous feed furnace with a reverberatory flame across the top of the ore to drive off and carry the mercury vapour to a series of large brick condensing chambers. These chambers housed a complex of water filled steel pipes to cool the gases and condense the mercury. After passing through six of these chambers with a total condensing area of 8,000 square feet the gases were taken via a flue to a 50-foot brick chimney. The plant, not including the long flue, extended for a length of 220 feet and was covered with an iron roof (Figure 5). As well as distilling the mercury it was planned to extract copper from the roasted residue by leaching with dilute sulphuric acid generated with the condensed mercury.[62] The residue was stockpiled but does not appear to have ever been treated on site.

Initial trials of the plant commenced in February 1913 with the treatment of eight tons of ore. It was found that the water supply to the large condensers was insufficient to counter the intense heat of the furnace resulting in most of the mercury reaching the flue, where at least some of if was found coating the walls as adhering globules.[63] A decision was made to increase the water pumping capacity from 3,000 to 18,000 gallons per hour and to build a dam across the creek to provide more water. During this trial the oil engine running the crusher broke down and had to be replaced by a steam engine.[64] Other modifications and improvements were made over the rest of the year that significantly delaying any large-scale mercury production.

In March 1914 the modified plant operated for a few days and some of the condensers were opened to reveal large globules of mercury running on the floor, including in the No. 1 condenser next to the furnace. The directors who visited and inspected the works on the 25th of March were satisfied that the plant was now operating well and were of the opinion that 'the process was without doubt one of the best in existence'. They agreed that the plant should continue to process the stockpiled ore and that the company should turn its attention so as to thoroughly develop the various lodes. However, the secretary noted that this would require deepening of the main shafts and installation of winding machinery, necessitating a call for further capital.[65] It was decided to run the plant continuously for two to three months before doing a clean up as it was found that 90 per cent of the mercury was depositing as tiny droplets within soot in the condensers and it was felt that this should be allowed to build to a significant thickness before trying to extract the dispersed mercury.[66] With the exception of a few days when heavy rain had made the ore too wet to treat, the plant was kept running until July.[67]

Figure 5: *View of the mercury reduction works of the Pulganbar Quicksilver And Copper Mining Company at the official opening on 5th August 1914.*



Source: Photograph, Walter Stevens, Grafton Photographics.

The reducing works were officially opened on the 5th of August 1914 when, at the invitation of the directors, a gathering of shareholders from the Richmond and Lower Clarence districts, as well as Sydney, arrived at Pulganbar in a convoy of 16 cars, a lorry and other vehicles. More than 80 visitors were shown over the mine workings and the plant, where some condensers were opened so that globules of mercury could be seen. Several prospecting dishes of mercury were also on display for inspection by the guests prior to lunch.[68] Over the year 680 tons of ore were processed and when the condensers were cleaned up in early 1915 they yielded 1,288 pounds of mercury.[69] This represented a recovery of less than 0.1 per cent from ore going up to 5 per cent, suggesting that the reducing process was far from 'one of the best in existence'. It appears that most of the mercury vapour escaped up the chimney or into and through the brickwork of the condensing chambers.[70]

In early 1912 the Yugilbar Cinnabar Company was floated on a modest basis to further develop the deposits at Yugilbar.[71] Mining recommenced and at some stage the Pulganbar Quicksilver and Copper Mining Company appears to have acquired or joint ventured with this group. During 1915, 200 tons of ore were raised at Pulganbar and another 200 tons at the Yugilbar mine, with eight tons transported to the Pulganbar reduction works.[72] The additional production of mercury from this material, reported in 1916, was about 817 pounds valued at £180.[73] There was no reported production after 1916 and the whole operation appears to have ceased at this time.

Other discoveries and occurrences

Other discoveries of mercury were made in eastern Australian during the nineteenth century, but all proved to be minor occurrences. For a number of years, cinnabar had been found in alluvial gold workings at Spring Creek near Bingara, 90 miles (145 km) north of Tamworth in northern New South Wales (Figure 1). In 1890 the source was traced to a dyke-like body of decomposed serpentinite. T.W.E. David from the NSW Geological Survey who inspected the discovery noted that 'lode cinnabar had been found in only two shafts, 40 and 25 feet deep, 15 feet apart'. He described the cinnabar as 'disseminated through the body of the dyke in small spots, from the size of a small pin's head up to that of a pistol bullet. It also occurs in thin films in joints in the dyke'. A carefully selected 10-pound sample was crushed and assayed by both dry and wet chemical methods indicating 0.01 per cent of metallic mercury. Aid from the prospecting vote was granted to Marsden and party to deepen the most promising shaft and test the deposit to a depth of 100 feet, but at 78 feet the work was abandoned, ostensibly due to an influx of water.[74]

About 1894, W.T. Pullin discovered cinnabar in a quartz vein while gold prospecting at Bark Hut Creek, a tributary of Corindi Creek near Woolgoolga on the north coast of New South Wales (Figure 1). Further work by a prospector called Macintosh in 1908 and by T. Russell and W. Riddell in 1910 located other occurrences in this area. The latter party obtained aid from the Prospecting Vote to sink a shaft to 25 feet on a narrow quartz vein, but the results were discouraging. Samples sent for assay were found to contain less than 0.5 per cent mercury with traces of gold and silver.[75]

During 1967 this locality was examined using modern exploration methods but nothing significant was revealed. Other mercury occurrences in New South Wales have been reported at Wild Cattle Creek in the Dorrigo region, at Tabulam and Pretty Gully in the Clarence district and at Barraba and Trunkey.[76]

Native mercury was discovered in the Willunga area of the Mount Lofty Ranges in South Australia in 1885 by August Saupe, a German prospector searching for gold.[77] Saupe had driven an adit into the side of a hill near Meadows Creek and noticed tiny droplets of mercury appearing on the surface of the rocks. In 1891 a group known as the Willunga Mercury Syndicate prospected the area and excavated a second adit. Others also took out claims totalling 2,400 acres. When the South Australian Inspector of Mines, J.V. Parkes visited the site he appeared sceptical of the discovery, as it was metallic mercury. He stated that he was 'at a loss to understand how the mercury which has been seen came there' possibly implying that the site had been salted.[78] Subsequent inspections, including those by W.G. Gibson and later in 1891 by H.Y.L. Brown, Government Geologist, confirmed the occurrence was genuine.[79] Prospecting activities continued until the end of the year, but no significant deposit or source for the metallic mercury was found. Eighteen years later there was further prospecting in a large area around this site by a Melbourne syndicate directed by H.E. Rowe, A.S. Woolcott, J. Cunningham, J. Turnbull and Hans W.H. Irvine (MHR). In December 1910 this group floated the Willunga Quicksilver Mines with capital of £10,000 in 5,000 £2 shares, the float being oversubscribed.[80] The following February the general manager, A.G. Holroyd, reported that two pounds of mercury had been obtained by panning a quantity of ore and that Mr J.H. Levings had been sent from Melbourne to inspect the site with a view to ordering machinery.[81] By April the company had tested the prospect by extending the adits and sinking a 50-foot shaft. This work revealed globules of native mercury in decomposed clay material within a sequence of sandstones and schist carrying some pyrite, but no primary cinnabar or significant mercury mineralisation. In June some of the Melbourne shareholders who were uneasy with the lack of success suggested that the company be wound up, but a group of South Australian investors considered this premature and recommended that prospecting, including drilling of some boreholes, continue. Levings, now the manager, reported on an assay received from the School of Mines of some pyrite concentrate from the mine that indicated 36 ozs of gold and 6 ozs of silver to the ton and a little mercury. This was thought by some to be too good to be true.[82] Work continued and in August the manager reported a borehole had reached 90 feet having passed through a graphitic zone into schist with quartz veins carrying a considerable amount of pyrite. Assays in Melbourne of two drill-hole samples indicated gold of around 1 oz per ton.[83] Development work continued into September, including a cross cut that intersected granite with pyritic quartz veins, but in October an extraordinary meeting of shareholders agreed to wind up and liquidate the company.[84] The following year the mine was renamed the Bullion and worked for gold. Fifty tons of lode material were mined but not found to be payable, so the mine was abandoned.[85]

In 1894 mercury was discovered about 16 miles (25.7 km) east of Jamieson in central Victoria (Figure 1). A gold prospector working the bed of a creek, later named

Quicksilver Creek, found globules of native mercury in his pan and traced the mercury back to the source in a diorite dyke and surrounding slate.[86] In 1898 Victorian Government Geologist R.A.F. Murray briefly reported on the site describing free mercury and small amounts of cinnabar in quartz. He proclaimed the discovery of only 'scientific interest', although he did suggest sinking a short distance to 'settle the question'.[87] Subsequently the Jamieson Quicksilver Company was formed to work the deposit and in August 1899 they retorted a quantity of mercury, which they sold to the local United Gleeson and Sailor Bill's goldmining company. The *Australian Mining Standard* erroneously proclaimed this as 'the first sale of quicksilver, the product of an Australian mine'.[88] About this time there was apparently a failed attempt to sell the lease to the Rothschilds in London. In 1928 a Melbourne company unsuccessfully attempted to reopen the mine,[89] though in late 1940 or early 1941 the Silver Creek Company was formed to work the deposit. They repaired the shaft and erected a small plant, but there appears to have been little if any production.[90] In 1901 there was also brief mention of an occurrence of native mercury in gold ore at one of the Jamieson gold mines.[91]

The first authenticated occurrence of mercury in Tasmania was described in 1935 by F. Blake, Acting Government Geologist. During a visit to the Jane River gold diggings in south-western Tasmania he noted minute amounts of alluvial cinnabar in the gold bearing drift. Subsequently the miners found it in greater abundance, but still in quantities too small to be of economic interest.[92]

After cinnabar had been found at Kilkivan other minor occurrences were discovered throughout Queensland including at Monsildale, Mount Perry, Montalbion, Gilberton, Nebo, Little River near Laura and in the O.K. Mine area in the Chilligoe-Mungana mining field.[93]

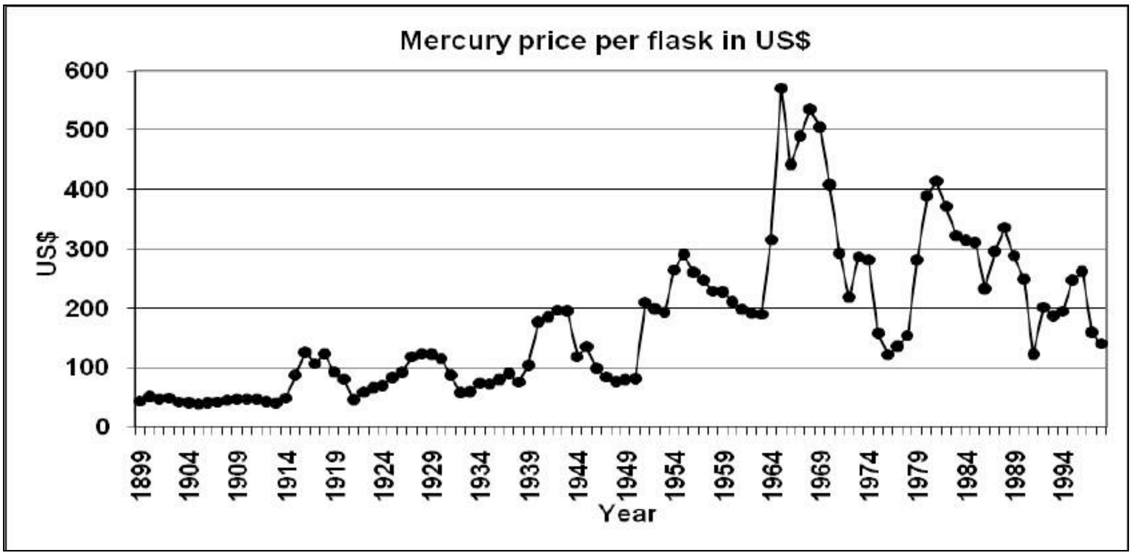
In Western Australia, small amounts of native mercury and amalgam have been reported from the oxidised zones of some gold deposits, they having probably been formed from the breakdown of primary coloradoite (mercury telluride).[94] Minor red mercury minerals resembling cinnabar have also been described from the upper weathered parts of the Broken Hill orebody. These have now been identified as complex mercury and silver halides, while cinnabar is yet to be verified.[95]

Attempts to revive mercury mining

As shown in Figure 6, during World War I the price of mercury rose to an all time high before declining to almost prewar levels in 1921 (though note as the prices are in current dollars, high inflation during the war, and deflation from 1929 distorts the picture). Thereafter, the price increased until the depression of the 1930s saw it drop again, only to rise once more as the clouds of World War II loomed on the horizon.

In 1930 there was a revival of interest in mercury mining at Kilkivan. The Queensland Quicksilver Development Company reopened the Bloodworth and Commotion lodes and built a new recovery plant, which was officially opened by Ernest Atherton, the Queensland Minister for Mines, in April 1932.[96] Lode mining continued until 1933 when the operations became unprofitable. Sluicing of alluvial deposits in the creek adjacent to these deposits was then attempted but with limited success.[97] This alluvial cinnabar had been discovered in 1891 near the Commotion lode and exploration with shafts and drilling in 1932 indicated 800,000 cubic yards of material suitable for sluicing containing an estimated 240,000 pounds of mercury.[98] A new deposit, Cirsons lode (Figure 3) was discovered in 1931 and purchased by Cirson's Cinnabar Mines Pty Ltd in 1934 and worked spasmodically until 1939.[99]

Figure 6: *Annual average mercury price in US$ per flask from 1899 to 1998*



Source: Data from R.G. Reese, *Mercury*, U.S. Geological Survey, 2001, p. 88. http://minerals.usgs.gov/minerals/pubs/commodity/mercury/430798.pdf

Note: Prices have not been adjusted to current dollars and reflect the marked inflation in $US since the 1950s. Mercury production is commonly reported in flasks. 1 flask = ca. 76 pounds (34.5 kg) of mercury.

During World War II the price of mercury again rose sharply (Figure 6) and further mining occurred at the Bloodworth and Commotion deposits at Kilkivan from 1940 to 1945. Cirson's lode was purchased by Q.S. Mines Pty Ltd, an Adelaide-based company, and worked in a small way until 1942. The high price and strategic need for mercury prompted additional prospecting and reinvestigation of known minor occurrences.[100] In 1940 Campbells Mining Pty Ltd developed a mercury mine with a three head stamp battery and retorts at Monsildale, in the Kilcoy district south of Kilkivan.[101] Production appears to have been limited or non-existent. In 1941 an unsuccessful attempt was also made to reopen the mines at Pulganbar. A syndicate of six formed a new company named Clarence Mines Pty Ltd with capital of £15,000 and plans were made to employ 15 miners.[102] Mining engineer J.H. Grant designed a new retort system, but it was apparently not constructed.

During the mining boom of the late 1960s to early 1970s, there was minor interest in exploring for mercury deposits. Carpentaria Exploration Company Pty Ltd conducted preliminary investigations at Pulganbar and later Woodsreef Mines took out an exploration area around the old mines at Yugilbar.[103]

Australia's limited mercury production

Why is it that Australia has never been a significant producer of mercury? It may simply reflect a lack of geological environments suitable for the formation of large mercury deposits, however, the continent has a diverse and almost complete range of geological settings, lacking only very recent tectonic-volcanic terrains, similar to the 'ring of fire' around the Pacific. Deposits in other parts of the world are hosted by rocks ranging in geological age from Recent back to early Palaeozoic (540 Ma). Large deposits occur as impregnations and disseminations of cinnabar in quartzites and slates (e.g. Almaden in Spain) as well as in fractured and brecciated, schists, quartzites and limestone (e.g. Idria in Slovenia). The Californian deposits occur as vein and fissure deposits in mixed slates, quartzites, serpentinite and limestone. Large mercury occurrences in China occur with calcareous shales and limestone in folded and faulted sedimentary sequences that have been subjected to regional basinal fluid migration possibly driven by increased crustal heat flow. Some mercury deposits are associated with granites and volcanic sequences marked by hot spring activity. There are rock types and geological settings similar to all of these in Australia. The known deposits in Australia are typically small vein-type occurrences or secondary alluvial deposits of limited extent. All were accidental discoveries facilitated by the distinctive characteristics of native mercury and cinnabar. From a geological point of view there appears to be no reason why significant mercury deposits should not exist in Australia. Interestingly however, modern geochemical exploration, particularly during the 1980s, at a time when there was an interest in using mercury vapour detectors to search for base metal deposits, has not turned up any major mercury occurrences.

Lack of interest in mercury exploration has probably been a key factor in lack of discovery. Despite the local demand for mercury in Australia during the nineteenth century and government incentives for exploration, there appears to have been limited systematic or deliberate prospecting. This was probably largely due to economic factors and the nature of the mercury industry. Mercury extraction in the nineteenth century was labour intensive and hence more economic in regions with lower labour costs. Hand picking was the main method of upgrading ore and although wet ore dressing was tried at a number of localities it was generally not successful. Even where labour was cheap profit margins were low. In 1888 it was estimated that the cost of production for mercury was about 90 per cent of the price.[104] Mercury tended to be a niche market and total demand could generally be met from a few very large deposits, allowing control by a small number of producers. From 1832 until 1863 the Rothschild family maintained a monopoly on production through their ownership of the mining leases at Almaden in Spain and contracts over the production from Idria.[105] Even after development of new large deposits in California in the 1850s, the Rothschilds still exerted a considerable control over production and marketing of mercury.

Historically, demand for mercury and hence price was strongly influenced by the ups and downs of the gold and silver mining industries (the main end users). Although large amounts of mercury were used in gold and silver production most of this mercury was recoverable from the amalgam during the precious metal separation.

Increases in demand were thus tied to periods of significant expansion of these industries but the combination of monopoly control, sudden changes in demand due to fluctuations in the gold and silver industries, demand spikes during periods of conflict and other political factors meant that the mercury price tended to be erratic. Following the Californian and Australian gold discoveries in the late 1840s, early 1850s, the price reached £27 a flask but by 1866 had dropped to £9. With outbreak of the Franco/Prussian War in 1870, there was a sudden rise to £29, followed in 1883 by a drop to £5 per flask.[106] Throughout the twentieth century there was also significant price volatility, particularly related to wars (Figure 6). During the late 1920s high prices were established and maintained by the Spanish-Italian, Mercurio Europeo cartel.[107]

The very limited production from the few deposits that were discovered in Australia, particularly large scale production from lower grade ores, partly reflects problems with processing. In the nineteenth century the two basic methods of mercury production from cinnabar were: enclosed heating with lime in a retort to produce mercury vapour and calcium sulphate; and open heating in air, for example in a reverberatory or shaft furnace, to produce mercury vapour and sulphur dioxide. In both cases the mercury vapour was condensed to liquid mercury in some form of condensing system. Most successful production in Australia was from retorting of high grade ore. Attempts at large scale production from low grade ore by reverberatory furnaces, for example at Pulganbar, were largely unsuccessful due to design faults in the plant and probably also to a lack of suitably experienced furnacemen, resulting in poor plant operation. Reduction of cinnabar in an open system required considerable skill, particularly in maintaining the correct furnace temperature. If the temperature was too high the mercury vapour formed mercury oxide, which together with other combustion products condensed as 'stupp' with the mercury. This material required additional treatment to recover the contained mercury. Poor control of the flow of gasses through the condensers could also result in significant loss of mercury vapour.[108]

In recent times the major factor limiting interest in mercury exploration has clearly been the declining demand for the metal, reflecting replacement or phasing out of most of its uses due to health and environmental concerns.

Conclusions

Australia has produced minimal mercury due to a lack of discovery of large deposits, the niche nature of the mercury market controlled by a small number of large producers, and more recently the declining demand for the metal. Small cinnabar deposits were discovered in eastern Australia during the nineteenth century and the history of these discoveries and the subsequent attempts to produce mercury is a fascinating one of buoyant optimism, hopeful investment and ultimate failure. The speculative entrepreneurism associated with the discoveries was typical of the mining industry of the time when it was very difficult to know the true extent of a surface prospect without the benefit of diamond drilling and modern geophysical prospecting methods. Every flashy surface discovery was a potential bonanza, until mining proved it otherwise. Of the discoveries, those around Kilkivan in southern Queensland resulted in the largest production of mercury, mostly from retorting of higher grade cinnabar ores. Attempts at large scale production by furnace roasting at Pulganbar in northern New South Wales failed, largely due to metallurgical difficulties.

Acknowledgements

My thanks to the National Library of Australia, the Clarence River Historical Society, Industry and Investment New South Wales and the Geological Survey of Queensland for help with locating information for this article.

Glossary of some terms used in the text

Adit = tunnel or horizontal opening to a mine.
Brecciated = naturally broken up by either brittle or hydraulic fracturing.
Dyke = an intrusive body of igneous rock that cross-cuts the intruded strata or other rocks.
Fissure vein = mineralisation infilling a tabular open cavity.
Granodiorite = an intrusive igneous rock composed of quartz, feldspar and mafic minerals with about equal proportions of alkali and plagioclase feldspar. Diorite is similar with a greater proportion of plagioclase and dark mafic minerals.
Sulphosalt = mineral containing a metal combined with sulphur and arsenic, bismuth or antimony.

Units

1 inch = 25.4 mm, 1 foot = 0.3048 m; 1 mile = 1.609 km,;1 acre = 0.4047 hectares; 1 ton (long) = 2,240 pounds (lbs) = 1.01604 tonnes; 1 hundred weight (cwt) = 112 pounds (lbs); 1 pound (lb) = 0.454 kg,;
1 (imperial) gallon = 4.4561 litres1 flask (of mercury) = ca. 76 pounds (lbs) = 34.5 kg.

Pre-decimal currency

£1 (pound) = 20s (shillings) and 1 shilling = 12d (pence)

Endnotes

[1] 'Mines and Metals – Mercury Deposits', *The West Australian*, 22 November 1940, p. 4.
[2] E.J. Kenny, *Cadmium and Mercury or "Quicksilver",* Bulletin No. 11, New South Wales Department of Mines, Geological Survey, 1924, p. 7; William E. Brooks, *Mercury*, 2007 Minerals Yearbook, United States Geological Survey, 2008, pp. 48.1-48.7.
[3] *Ibid.*
[4] J.E. Carne, *Mercury or "Quicksilver" in New South Wales,* Minerals Resources No. 7 (2nd Edition), New South Wales Department of Mines, Geological Survey, 1913, p. 18.
[5] *Ibid*., p. 21.
[6] *Ibid.,* p. 18.
[7] 'Telegraphic Despatches – Sydney, Friday', *The Argus*, 15 August 1868, p. 5.
[8] Carne, *Mercury or "Quicksilver",* p. 19.
[9] Quicksilver Mines at Cudgegong - Experimental Test of the Ore', *Sydney Morning Herald*, 2 March 1869, p. 5.
[10] 'Cudgegong Mining Company Limited', *Sydney Morning Herald*, 1 February 1870, p. 3.
[11] 'Mining Intelligence – Deposit of Cinnabar', *Sydney Morning Herald*, 3 February 1885, p. 9.
[12] *Ibid*.; Carne, *Mercury or "Quicksilver",* pp. 22-25.
[13] 'Cudgegong Mining Company Limited', *Sydney Morning Herald*, 1 February 1870, p. 3.
[14] Carne, *Mercury or "Quicksilver",* p. 25
[15] 'Through Queensland's Goldfields – The Kilkivan District', *Town and Country Journal*, 25 February 1888, p. 381; Dulcie Logan, *Where Two Rivers Run: A history of Kilkivan Shire*, 1988, Watson Ferguson and Co., Brisbane, pp. 92-93.
[16] 'Wide Bay Mining News', *The Brisbane Courier*, 11 December 1872, p. 3.
[17] 'Through Queensland's Goldfields – The Kilkivan District', *Town and Country Journal*, 25 February 1888, p. 381.
[18] 'Mercury Mine – A Queensland Venture', *The West Australian*, 26 April 1932, p. 12.
[19] Out in the Cinnabar Country', *The Queenslander*, 24 November 1877, p. 24; G. Blainey, *The Rush That Never Ended,* Melbourne UP, Carlton, 2nd edition., 1969, pp. 128-133.
[20] 'Out in the Cinnabar Country', *The Queenslander*, 24 November 1877, p. 24.
[21] 'Telegraphic – Gympie', *The Brisbane Courier*, 23 May 1874, p. 4.

[22] S.L. Hester, *Queensland Quicksilver Mines*, Issued by the Sydney International Exhibition, 1879, Gibbs, Shallard and Co., Sydney, 8 pp; Out in the Cinnabar Country', *The Queenslander*, 24 November 1877, p. 24.
[23] 'Queensland', *South Australian Register*, 8 January 1881, p. 2.
[24] 'Quicksilver Mines in Queensland', *Northern Territory Times and Gazette*, 10 July 1886, p. 3.
[25] 'Through Queensland's Goldfields – the Kilkivan District', *Town and Country Journal*, 25 February 1888, p. 381.
[26] 'Queensland Quicksilver Company London Feb 27', *Sydney Morning Herald*, 1 March 1886, p. 7; 'Monetary and Commercial', *Ibid*, 14 April 1886, p. 8.
[27] 'Quicksilver Mines in Queensland', *Northern Territory Times and Gazette*, 10 July 1886, p. 3.
[28] 'Mining Notes', *Morning Bulletin*, 18 June 1887, p. 5.
[29] 'Through Queensland's Goldfields – the Kilkivan District', *Town and Country Journal*, 25 February 1888, p. 381.
[30] 'Quicksilver Mines in Queensland', *Northern Territory Times and Gazette*, 10 July 1886, p. 3.
[31] 'Kilkivan Quicksilver Mines', *The Queenslander*, 21 January 1888, p. 107; 'Through Queensland's Goldfields – the Kilkivan District', *Town and Country Journal*, 25 February 1888, p. 381. Gully lode appears to have been part of the Queensland deposit, see S.L. Hester, *Queensland Quicksilver Mine,* map.
[32] 'Through Queensland's Goldfields – the Kilkivan District', *Town and Country Journal*, 25 February 1888, p. 381.
[33] 'Mining Notes', *Morning Bulletin*, 12 September 1888, p. 4.
[34] 'Supreme Court – Civil Jurisdiction', *Brisbane Courier*, 11 May 1888, p. 3; Captain W.H. Eldred had claimed a three quarter interest in the partnership and the Hesters and partner T.W. Donaldson challenged this admitting only a half share. During the court proceedings a compromise was reached whereby Eldred agreed to pay the others £1,000 and transfer to them 20,000 shares in the Queensland Quicksilver Estates Ltd, 'Judicial Affairs – Supreme Court', *The Queenslander*, 19 May 1888, p. 767.
[35] 'Epitome of News', *The Brisbane Courier*, 24 May 1888, p. 4; 'Gympie', *The Queenslander*, 26 May 1888, p. 840; *The Brisbane Courier*, 9 June 1888, p. 5.
[36] 'Passengers and Crew of the Quetta', *The Queenslander*, 15 March 1890, p. 505; 'The Discovery of Gold in British New Guinea', *Sydney Morning Herald*, 10 June 1911, p. 5.
[37] 'Death of Duke of Manchester', *The Queenslander*, 29 March 1890, p. 591.
[38] 'Country Mails – Wide Bay District', *The Brisbane Courier*, 15 September 1890, p. 7.
[39] J.H. Brooks, J.N. Syvret and J.D. Sawers, *Mineral Resources of the Kilkivan district*, Report no. 60, Geological Survey of Queensland, 1974, pp. 7 and 9.
[40] 'The Solferino District – Cinnabar', *Clarence and Richmond Examiner*, 20 December 1890.
[41] Carne, *Mercury or "Quicksilver"*, pp. 27-28.
[42] *Ibid*., pp. 29-32.
[43] *Ibid*., p. 32.
[44] 'Intercolonial Mining News', *Town and Country Journal*, 20 October 1900, p. 56.
[45] 'Late Mining', *Sydney Morning Herald*, 11 September 1899, p. 8.
[46] Carne, *Mercury or "Quicksilver"*, p. 39.
[47] 'Mining Intelligence', *Sydney Morning Herald*, 20 September 1902, p. 13; 'Great Australian Quicksilver Mining Company', *ibid*., 27 December 1902, p. 9.
[48] Carne, *Mercury or "Quicksilver"*, p. 39.
[49] *Ibid*., p. 39; 'General Mining News – Cinnabar on the Clarence', *Town and Country Journal*, 11 November 1908, p. 53; 'Pulganbar Quicksilver Mines of Long Ago: Copper Ore for Century', *Daily Examiner*, 8 October 1973, p. 10.
[50] 'Mining', *Clarence and Richmond Examiner*, 21 November 1908, p. 405; 'Abridged Prospectus Pulganbar Mineral Prospecting Company', *Sydney Morning Herald*, 21 November 1908, p. 22.
[51] Carne, *Mercury or "Quicksilver"*, pp. 40-41; 'Mining in the State', *Sydney Morning Herald*, 25 April 1911, p. 21.
[52] Annual Report of the NSW Department of Mines [hereafter ARNSWDM] for 1911, p. 65.
[53] Carne, *Mercury or "Quicksilver*, p. 41.
[54] 'Pulganbar Quicksilver and Copper' *Sydney Morning Herald*, 18 December 1912, p. 19; 'Pulganbar Quicksilver and Copper Mining Co. Ltd.', *Clarence and Richmond Examiner*, 24 December 1912, p. 7.
[55] 'Mining Notes', *Sydney Morning Herald*, 13 May 1912, p. 11.
[56] 'Quicksilver Production', *Town and Country Journal*, 7 July 1900, p. 25; ARNSWDM for 1900, p. 65.
[57] 'Pulganbar Quicksilver and Copper', *Sydney Morning Herald*, 18 December 1912, p. 19.
[58] 'Pulganbar Mining Co. Ltd.', *Clarence and Richmond Examiner*, 6 July 1912, p. 4.

---

[59] 'Pulganbar Quicksilver and Copper Mining Co. Ltd – Second Annual Report', *ibid.,* 24 December 1912, p. 7.
[60] 'Pulganbar Quicksilver and Copper Co. Ltd.', *ibid.*, 9 May 1912, p. 4.
[61] ARNSWDM for 1912, p. 62.
[62] 'Pulganbar Quicksilver and Copper', *Clarence and Richmond Examiner*, 8 August 1914, p. 3.
[63] 'Mining – Pulganbar Copper Mining Co.', *ibid.,* 18 February 1913, p. 4.
[64] 'Pulganbar Quicksilver and Copper' *Sydney Morning Herald*, 31 March 1913, p. 11.
[65] 'Pulganbar Quicksilver and Copper Mine – Trial Run of Condensers', *ibid*., 30 March 1914, p.11.
[66] 'Pulganbar Copper Mining Co.' *Clarence and Richmond Examiner*, 30 April 1914, p. 2.
[67] 'Mining', *ibid*., 11 July 1914, p. 9.
[68] 'Pulganbar Quicksilver and Copper', *ibid.*, 8 August 1914, p. 3.
[69] ARNSWDM for 1914, p. 67; *Ibid*., p. 63.
[70] The problem of mercury loss using the furnace method of extraction was well known and related to the high volatility and high density of the metal. In the nineteenth century losses were commonly about 50% of the mercury and as low as 6-8% in the best furnaces. As an example of leakage of mercury, 153,000 pounds of mercury were recovered from the ground beneath a furnace at New Idria, California, where the metal had penetrated 27 feet to bedrock, J.E. Carne, *Mercury or "Quicksilver*", pp. 13-14.
[71] 'Prospectus of the Yugilbar Cinnabar Company', *Clarence and Richmond Examiner*, 22 April 1912, p. 12.
[72] ARNSWDM for 1915, p. 63.
[73] *Ibid*., for 1916, p. 63.
[74] 'Discovery of Cinnabar near Bingara', *Sydney Morning Herald*, 4 June 1891, p. 7; ARNSWDM for 1891, pp. 234-39; Carne, *Mercury or "Quicksilver*", pp. 26-27.
[75] Carne, *Mercury or "Quicksilver"*, pp. 41-42.
[76] *Information Brochure No.* 12:*Mercury*, Geological Survey of New South Wales, 1968, 7 pp.
[77] Record of Mines Summary Card No. 49, Willunga Mercury Mine, SARIG. https://sarig.pir.sa.gov.au/Map
[78] 'Mercury Discoveries near Willunga', *South Australian Register*, 17 April 1891, p. 3; Miscellaneous – The Alleged Quicksilver Discovery', *ibid.,* 18 April 1891, p. 7.
[79] 'Mercury Discoveries near Willunga', *ibid.,* 17 April 1891, p. 3; Carne, *Mercury or "Quicksilver"*, p. 49.
[80] 'Mining', *Examiner*, 6 December 1910, p. 2; Record of Mines Summary Card No. 49, Willunga Mercury Mine, SARIG; 'Willunga Quicksilver Mines' *Sydney Morning Herald*, 19 December 1910, p. 11.
[81] 'Willunga Quicksilver Mines', *The Advertiser*, 21 February 1911, p. 12.
[82] 'Willunga Quicksilver Mines', *ibid*., 14 June 1911, p. 12.
[83] 'Managers Reports', *ibid*., 27 July 1911, p.13; *ibid*., 18 August 1911, p. 14.
[84] 'Monetary and Mining', *The Argus*, 21 October 1911, p. 20; 'Willunga Quicksilver Mine – Liquidation Proceedings', *The Advertiser*, 25 October 1911, p. 18.
[85] Record of Mines Summary Card No. 49, Willunga Mercury Mine, SARIG.
[86] 'Mining - The Victorian Quicksilver Find', *Barrier Miner*, 16 March 1894, p. 3; *ibid*., 19 March 1894, p. 2; Carne, *Mercury or "Quicksilver"*, p. 48-49.
[87] R.A.F. Murray, *Report on the country between Woods Point and Jamieson*, Department of Mines Victoria for 1898, p. 3.
[88] Carne, *Mercury or "Quicksilver"*, p. 49.
[89] 'Quicksilver – Unique Victorian Enterprise', *Evening Post*, 17 Haratua [May] 1928, p. 6.
[90] W.D. Birch, The Jamieson mercury deposit, Victoria, *Australian Journal of Mineralogy* v. 9, no. 1, June 2003, pp. 33-38.
[91] 'Victoria', *The West Australian*, 4 March 1901, p. 5.
[92] 'Mercury Found – The Jane River Diggings', *Examiner*, 22 November 1935, p. 6.
[93] L.C. Ball, *Certain Mines and Mineral Fields in North Queensland*, Geological Survey of Queensland, Publication no. 222, 1910. pp. 21-32; 'Economic Geology – Mining and Mineral Areas in Queensland', *Cairns Post*, 11 March 1926, p. 9; 'Mines and Metals – Mercury Deposits', *The West Australian*, 22 November 1940, p. 4; Carne, *Mercury or "Quicksilver"*, p. 48.
[94] E.S. Simpson, *Minerals of Western Australia,* vol 1, 1948, W.A. Govt. Printer, Perth, pp. 64-65.
[95] W.D. Birch (ed.), *The Minerals of Broken Hill*, Broken Hill City Council, 1999, p. 135.
[96] 'Quicksilver Plant Opened in Queensland', *The Advertiser*, 26 April 1932, p. 6. Ernest Atherton, member of the prominent Atherton family of Queensland, had been a baker and butcher in the small

settlement of Almaden, near Chilligoe in north Queensland. This town was named after the famous mercury locality in Spain, although it does not appear to have produced any mercury.

[97] J.H. Brooks, *Mineral Resources of the Kilkivan district*, Report No 60, Geological Survey of Queensland, 1974, p. 9.

[98] 'Mercury Mining – Kilkivan Company's Enterprise', *The Brisbane Courier*, 9 August 1932, p. 7.

[99] Brooks, *Mineral Resources of the Kilkivan district,* p. 9.

[100] 'Mines and Metals – Mercury Deposits', *The West Australian*, 22 November 1940, p. 4.

[101] 'Monsildale Mercury Mine', *The Courier Mail*, 29 May 1940, p. 10.

[102] 'Grafton', *The Courier Mail*, 3 December 1940, p. 11.

[103] 'Pulganbar eastern cinnabar workings Clarence River' Geological Survey of New South Wales, Open File Report, Map (R00042609).

[104] Becker, *Geology of Quicksilver Deposits of the Pacific Slope*, U.S. Geological Survey Monograph, 13, 1888, p. 1, cited in J.E. Carne, *Mercury or "Quicksilver"*, p. 1.

[105] Alma Parra, *Mercury's agent: Lionel Davidson and the Rothschilds in Mexico*, p. 28. htpp//:www.rothschildarchive.org.

[106] T. Egleston, *Metallurgy of Silver, Antimony and Mercury in the United States,* v. 2, 1890, p. 799, cited in Carne, *Mercury or "Quicksilver"*, p. 1.

[107] J.W. Pennington, 'Mercury – A materials survey', *U.S. Bureau of Mines Information Circular 7941*, 1959, 92 pp.

[108] Carne, *Mercury or "Quicksilver"*, pp. 12-16; S.L. Bensusan, 'Quicksilver', *Town and Country Journal*, 8 January 1870, pp. 10-12.