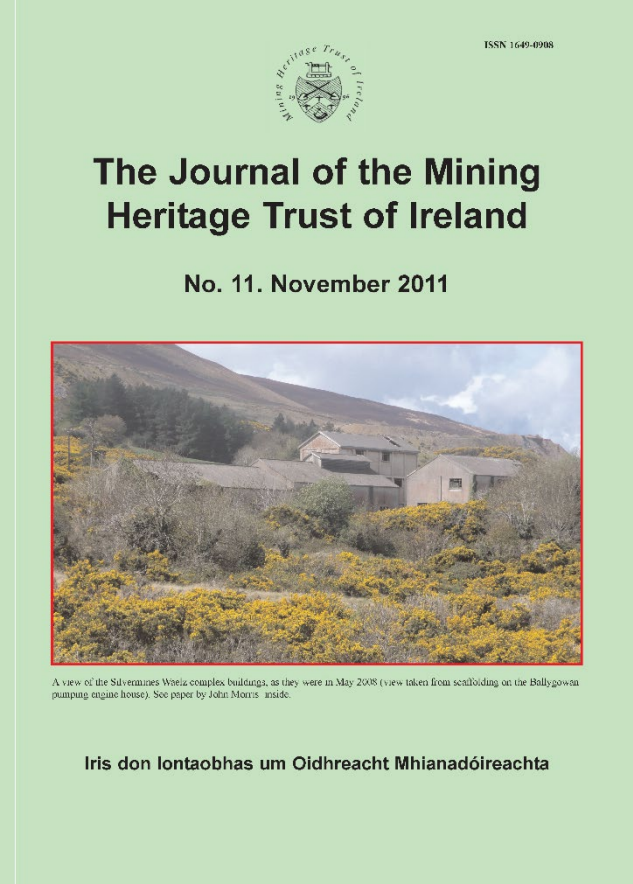

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PHILIP HENRY ARGALL (1854-1922): THE REMARKABLE LIFE AND CAREER OF A CORNISH-IRISH MINING MANAGER, ENGINEER AND METALLURGIST

by Sharron P. Schwartz and Martin F. Critchley

Abstract: The life and works of Philip Henry Argall, a largely self-taught man who gained his early mining and metallurgical experience in Avoca, Co. Wicklow, capture the dynamics of mining migration and the global nature of the metalliferous mining and smelting industry and its attendant labour market in the nineteenth and early twentieth centuries. Migration networks spanning Cornwall, Wales, Ireland, the United States and beyond are revealed, and details extracted from a number of papers presented to learned societies of his ingenious innovations in mineral processing at Avoca and elsewhere, are described. Argall was interviewed by Cornish-American mining engineer and journalist, Thomas Arthur Rickard, who published details of his early career and his subsequent successful practical work to commercialise gold cyanidation in the Western US. This interview was republished following Argall's death and some of the material contained within it informs this article (Rickard 1922).[1] Argall's patient experiments with cyanidation revolutionised mineral processing in the United States and beyond, earning this tenacious Cornish-Irishman a place in the history books. *Journal of the Mining Heritage Trust of Ireland*, **11**, 2011 47-64.

CORNISH ANTECEDENTS AND CO. DOWN CONNECTIONS

Philip Henry Argall [2] was born on 27 August 1854 to Philip and Sarah Argall at Newtownards, Co. Down, Northern Ireland.[3] His father (1815-1887) was a mining engineer and a native of Peterville, St Agnes Cornwall, born of a family long settled in the St Agnes and Perranzabuloe area. His mother, Sarah McCullam, was of Ulster-Scots descent.[4] Philip Henry's father undoubtedly knew about the lead mines near Belfast as they had attracted numerous Cornishmen, including Captain Silas Evans, from his native parish of St Agnes. Moreover Captain Evans was a relative, his mother was an Argall, and he had migrated to Newtownards sometime after 1841 after working his way up through the mining ranks in the lead mines of Wales and the Isle of Man. He was firstly employed as Agent by mining entrepreneur, John Taylor (1779-1863), at his Ulster Mining Company's Conlig Mine (Woodrow 1978). As Conlig was a Taylor enterprise, as elsewhere in the world where Taylor had mines, Cornish mineworkers were favoured and high pressure Cornish steam engines deployed. The truncated remains of a very overgrown engine house may still be seen at this mine.[5]

In 1846 Evans took the Manager's position at the rival Newtownards Mining Company at nearby Whitespots. In 1850 a Cornish newspaper reported that the adventurers had awarded Captain Evans with a service of plate for his success in bringing prosperity to the Newtownards enterprise that was comparatively poor when he took up his post (*WB* 1850). Whilst a relatively young man, Philip Argall senior, like Captain Evans, had worked in mines in Wales and on the Isle of Man before arriving at Newtownards. Philip Henry Argall visited the

1 Rickard's interview with Argall was one of many conducted with prominent mining men in the USA in the early twentieth century and that had been previously published in the *Mining and Scientific Press*. Much of the material for this article has been gleaned from the interview Rickard undertook with Argall. The two men, then living in the United States, knew each other well having both come from Cornish stock. Thomas Arthur Rickard's father Thomas, a mineral surveyor, was born at Porthtowan Commons, Illogan in 1834, the son of James Rickard, a copper and tin mine Agent. T. A. Rickard, founder of *The Mining Magazine* and editor of *The Engineering and Mining Journal*, has been described by American mining historian, Clark Spence as, 'indisputably one of the world's foremost mining specialists in the half-century following 1890' (Spence 1995).

2 According to Pawley-White (1981), 'Argall' is a locative Cornish language surname meaning 'a secluded place, shelter or retreat'. It is of great antiquity and has been traced to the Parish of St Budock in the C13th.

3 The description of Argall on his US Passport application of 29 November 1919 in Denver, describes him as '5 ft 9½ ins tall, with a full face and a full chin, a high forehead, brown eyes, a regular nose, a moustached mouth. He has brown hair and is of a fair complexion. He has no distinguishing marks'. Apparently, he was thought to resemble President Grover Cleveland.

4 The couple were married 1 July 1853 at Bangor, Church of Ireland, North Down, in the presence of William H. Martin and George Moore.

5 Woodrow erroneously assumes Evans to have been Welsh. Evans, noted as of Newtownards near Belfast, Ireland, married Susan, third daughter of Cornishman, Captain Richard Rowe of St Agnes, at St Andrews Church, Holborn, London, 16 February 1847 (*WB* 1847). Rowe's son, also named Richard, and a brother to Susan, worked at Newtownards before migrating to the Isle of Man in 1845 where he held the position of Captain of the Laxley Mine and Agent of the Laxley Mining Co. Evans later returned briefly to the Isle of Man where he was tasked with the liquidation of the North Foxdale Mine in 1870 (*MS* 1870). As the Newtownards Mining Company (1828) was a Manx group, this accounts for the networks of labour migration between the Isle of Man and Northern Ireland. Additionally, Taylor had charge of rich lead mines in Flintshire and Cardiganshire, run on the Cornish system, employing Cornish labour, that account for labour migration networks between Cornwall, Wales and Northern Ireland.

Newtownards mines in 1911 to find a typical Cornish mining scene, apart from the ruined tower of the famous wind-mill that operated the crushing machinery in the early 1850s. He recalled seeing the large dumps of jig-tailing adjoining it which bore ample testimony to the power developed by this huge wind-mill, of which he heard his father speak so often. 'In average weather it ran the whole dressing-works,' he noted, '… but as a local wit remarked, 'she had her off days, and in that respect was more human than the steam pumping-engine that was never affected by the weather' (Rickard 1922, 6).

THE WICKLOW MINES

Argall's father remained at Newtownards until 1858 when he moved south to take up a position at the Cronebane copper mine in Avoca, County Wicklow, which, with the Tigroney sett, was being worked by Williams and Co., mining entrepreneurs from Scorrier, Cornwall, who had acquired the lease of these mines in East Avoca in 1833 (MS 16,337, NLI). The Argall family set up home initially at Ballinapark. Philip Henry was the eldest of nine children (seven boys and two girls) most of whom were baptised at the small Methodist chapel that had been built to service the needs of the Cornish community in Avoca. Argall's earliest recollection of mining was an attempt at gold mining on the Aughrim River, a tributary of the Avoca River:

> I remember a Californian miner in a red-flannel shirt; he was boss of the New Diggings. It was the first red shirt I ever saw. In the land of the "sleeved waistcoat" he wore no vest; his hat had the widest brim it had been my privilege to gaze upon. For a year he was the hero of my childhood, and to this day nothing in my early life stands out so clear-cut and so vivid as that Californian gold miner in 1859, with his red shirt, sleeves rolled up, hat tilted back. I see him yet, prominently posed on the bank shouting orders to the workmen below. (Rickard 1922, 6).

It seems remarkable that an American should have been employed in an Irish mineral field, as one automatically assumes the flow of labour to be towards the Americas from Ireland. Even if he was a return Irishman, it underlines the global nature of the mining industry at that time and the fact that the Californians were regarded as pre-eminent in placer gold mining. The young Argall was intrigued by what he had seen and, stealing up to one of the sluices after the men had ceased work, he found something yellow, about the size of a wheat grain. 'They told me it was a gold nugget, the first found at that place' he recounted. This initiated a lifelong interest in mineral exploration. 'I date my mining career from that event' stated Argall (Figure 2).

Wicklow had already witnessed a gold rush along the Goldmine River in 1795, the government introducing a systematic system of streaming in response to this in 1797 under the direction of Messrs Mills, King and Weaver, which flourished until the 1798 Rebellion. Work resumed by the government in 1801 when a

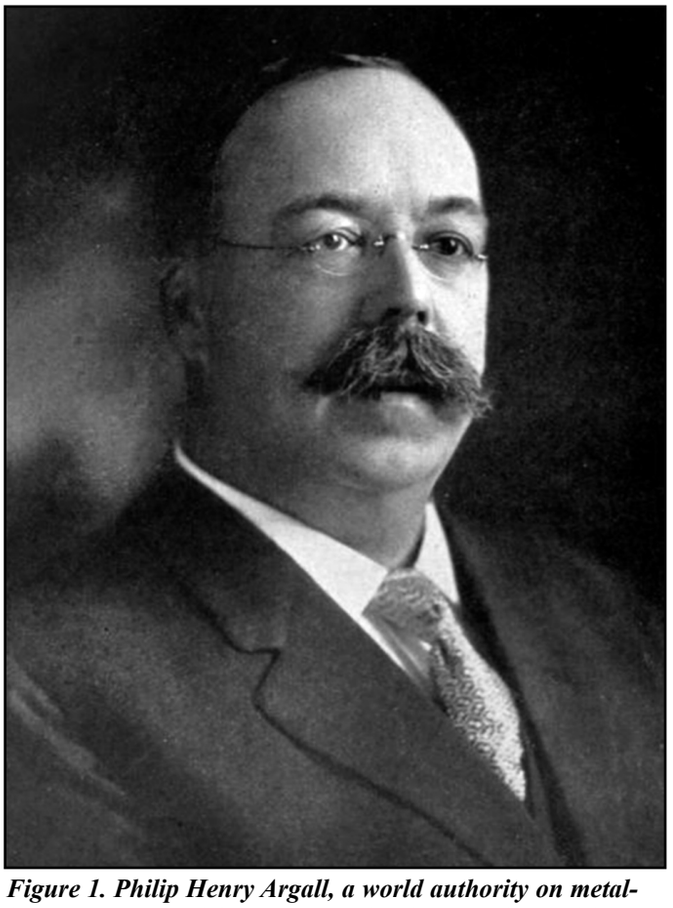


Figure 1. Philip Henry Argall, a world authority on metallurgy. Reproduced from T. A. Rickard's Interviews with Mining Men, 1922.

tunnel was dug into Croghan Kinsella mountain and extensive trenches excavated in search of the source of the alluvial gold, without success (Hull 1888). However, as Argall's reminiscences illustrate, gold continued to be recovered in the local rivers by commercial companies such as Messrs. Crockford and Co. (granted a twenty one year lease in about 1840, a short-lived operation headed by an experienced Cornish miner), and by local placer miners working long toms and by panning.

In order to discover the source of the alluvial gold, Argall's Californian hero and his men collected the float-quartz from the hillsides and erected a stamp mill to crush it. According to Argall, the hard quartz got the better of the cast-iron heads. Their next move consisted of calcining the quartz in a sort of lime-kiln and quenching it with water before stamping. 'The roasted quartz went through the battery without incident, that I can recall', noted Argall, 'then came the clean-up, and, as I learned afterward, no amalgam, so the mercury was finally volatilized in an iron ladle over the forge-fire and, like the baseless fabric of a vision left not a wrack behind'.

> That process I saw, and realized some of the disappointment. The Irish quartz-rock proved too much for my red-shirt hero, who went out of my life, as it were, in mercurial vapor. (Rickard 1922, 7).[6]

[6] Argall notes that in 1875 he assisted G. Henry Kinahan of H. M. Geological Survey, in looking over the placer workings. Some three or four men were at that time eking out a scant existence with pick and pan. He re-visited the place in 1901 and heard that one old gold-miner was still active in the district.

Figure 2. The search for alluvial gold below Croghan Kinsella Mountain, 1804. A similar scene was witnessed in this area in the early 1860s by Argall when a small child that stimulated his interest in mining. Courtesy of the National Library of Ireland.

Argall's childhood reminiscences might record the activities of the mysterious 'Suter' (note the misspelt German surname, synonymous with the Californian gold rush), about which little is known beyond the fact that it worked the Coolbaun Stream and tributaries; Derry Water at the Ballycoog Ford and Ballintempe Stream, its tributary (Hull 1888).

Alternatively, this could be a recollection of the early activities of the Carysfort Mining Company, established in 1858 to work the mineral lodes of the district, obtaining the gold royalties in 1862. Captained by Cornishman, Silas Evans, who had managed the lead mines of Newtownards, Carysfort instituted extensive trials (Cowman 2003). The company 'costeened' Croghan Kinsella and neighbouring mountains to a considerable extent and the quartz of the district was collected, crushed, and examined, including that obtained from levels within the Moneyteige and Ballintemple Mines. A head of stamps was erected at the latter mine near Woodenbridge. Some of the more promising lodes of quartz had shafts driven on them a couple of fathoms deep. The researches of the company indicated deposits in the valley showing a wide distribution of gold particles, some of which could be described as nuggets found at the upper parts of the streams towards their sources. The largest nugget found weighed 320 grains, but the company ceased operations for gold in about 1865 after having obtained £203 6s. worth of the precious metal but without finding the mineral in its original matrix or vein (Kinahan 1883). According to McArdle, some 300 kg of gold was discovered in this area over the course of roughly a century from 1795 (McArdle 2003, 2011).

With adolescence came hard work at the Wicklow mines and the learning of practical details both above and below ground. An exceptionally gifted lad, Argall grew up among the mines and metallurgical works in Ireland, absorbing practical details as he grew and learning the scientific details later. Before he reached his sixteenth birthday, he had completed a grammar-school type education and had obtained a grounding in Latin and familiarity with Macaulay, Shakespeare and the English Bible. At that age he was labouring ten hours a day on the dressing floors of the Tigroney mine, receiving a penny an hour in payment. 'I soon learned about all that was then known regarding jigs, buddles, and copper-ore dressing, as well as the method then used in precipitating copper from mine-waters.'

Apparently Argall had the happy gift of arousing the personal interest of his older acquaintances, some of whom took pains to help him by the loan of books or apparatus.

At seventeen, he was studying three evenings a week with a tutor after an eight hour shift underground where he learnt all the skills of a hard rock miner: driving, raising, sinking and stoping in both hard and running ground. The work was arduous and the conditions underground were poor. Argall later recalled that huge falls of ground on the great pyritic lode in Tigroney and Cronebane were common and the temperature in the stopes of both setts was intense, seldom below 100 degrees F., and in some cases attained 140 degrees F. The water drops that fell from the roof of the stopes 'were simply saturated solutions of sulphate', and he recounted how this acid water caused nasty sores on the backs and arms of the semi-naked miners, adding that one man lost the sight of his right eye by the corrosive action of a single water drop (Argall July 1906).

Argall also took two hours daily instruction from Captain Chamley, an ex-officer of the Ordnance Department of the British army, on mathematics and surveying.

> We had at that time a sort of mining college on Stephens Green, in Dublin. I believe it was called the Royal College of Science for Ireland. The Wicklow mines were but forty miles from Dublin and we saw much of the professors; they were very kind to me, giving me books to study and directing my reading in chemistry. I particularly recall Prof. J.P. O'Reilly, Professor Robert Galloway… I owe much to these men…(Rickard 1922, 8).

However, he notes that he owed the most to a scientist whose name he could not recall, a gentleman he had shown through the mines:

> … we were lunching together, when he asked me about the blow-pipe. I knew nothing about it. His conversation greatly impressed me; he went out and scraped some of the mud off the road, explaining that the minute pieces of hoof and hair in the mud should react for ammonia in the closed tube. To my astonishment it did. He fixed me up with a blow-pipe and a list of books. These I procured, and set to work. He insisted on checking over my notes and within six months I was quite handy with the blow pipe. To this scientist I am also indebted for notes, how to record the essential information in brief form, arranged for ready reference…(Rickard 1922, 8).

That blow-pipe was to become the key to a whole world of rudimentary metallurgy, for a blow-pipe and a piece of charcoal constitute a blast-furnace in miniature.

Inspired, Argall purchased some apparatus and reagents 'to putter along with', but at twenty (1874) was fortunate in being able to pick up a complete laboratory apparatus, including reagents, at the defunct Connary (also spelt Connorree and variants) Mine. Situated on the hillside above Tigroney and Cronebane, it was operated by the Connorree Mining Company in East Avoca. The equipment was German, for elaborate experiments had been made by German metallurgists between 1866-1868 into the feasibility of kernel-roasting and copper-leaching of the Connary ores, the mine then under the superintendence of George W. Maynard. [7]

> I visited the plant almost every day on my way home from school; the laboratory always commanded my admiration, and years afterward when I obtained possession of it I was a proud boy indeed, though I had borrowed more than half the money I paid for it. (Rickard 1922, 9).

Argall made good use of this laboratory and soon got out of debt by making sulphur and copper assays; previously the former had been sent to Dublin and the latter to Swansea or Cornwall for assay.

In 1872 Argall's father had left Avoca to take up a position in a colliery in County Tyrone.[8] The eighteen year old Argall remained in Wicklow. At nineteen he was appointed a shift-boss in the Cronebane mine and two years later was the assistant-manager earning him the title of Captain, as Cornish customs prevailed on the Wicklow Mines. In December 1875 he was considered sufficiently experienced to be appointed Agent in charge of the Cronebane mine. On 31 August of the following year he married Frances Ellen Oates of Knocknode at Avoca, the daughter of Cornishman, Captain George Oates of Blackwater near Scorrier, who managed the Cronebane Mine[9]. He notes that Captain Oates was, 'a man to whom I am indebted for much of my early training in engineering ethics'. Argall's knowledge of the mineralogy of the Wicklow Mines and his mastery of surveying and mapping were evident from his descriptive paper and section of the Eastern Avoca Mines, *The Geological and Mineralogical Districts of Avoca*, which was awarded Colonel Tremayne's special premium of three pounds (first prize) for the best plan and section of any mining district at the Royal Cornwall Polytechnic Society's exhibition in 1878 (Report, 1878) (Figure 3). The following year his paper entitled, *Notes on the ancient and recent mining operations in the Eastern Avoca District*, was read before the Dublin Royal Society and was later published in its proceedings and in another scholarly journal (Argall 1879).

7 Maynard, most probably a Cornishman, later worked in the mines of New Mexico, USA.

8 Philip Argall senior died in Dungannon in 1887. He is interred at Drumcoo in the civil parish of Drumglass, Co. Tyrone, Ireland. A headstone with rail surround states: *In Memory of Philip Argall of St Agnes Cornwall, England, who died at Dungannon 2 Decr 1887 aged 72 years. Also his wife Sarah, who died 13th April 1906. Interred at Bangor.*

9 The couple had six sons and five daughters; one other child died unnamed.

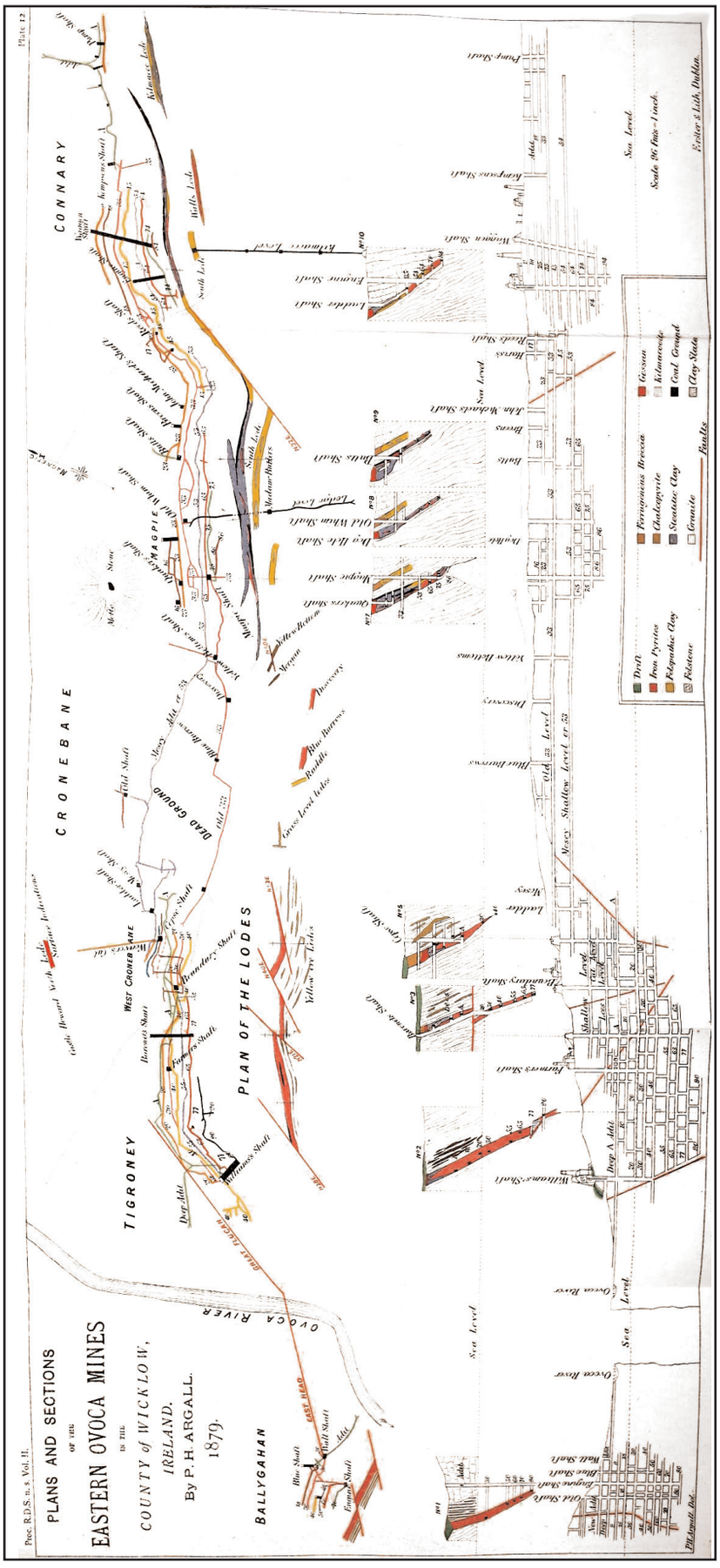


Figure 3. Plans and Sections of the Ovoca Mines produced by Argall in 1879 and published in the Scientific Proceedings of the Royal Dublin Society, New Series Vol. II, 1880.

HYDROMETALLURGY: COPPER PRECIPITATION EXPERIMENTS AT CRONEBANE

The waters of the Cronebane Mine were very rich in copper in solution and this fact had been realised over a century before Argall experimented with cementation. Its origin in Wicklow is reputed to have its roots in Cornwall, where precipitation of copper from the salts contained in mine water had been observed at Chacewater Mine (Wheal Busy) in 1728. A group of Wheal Busy workers migrated to work at the Cronebane Mine in the mid-eighteenth century, then under the superintendence of Captain Butler of Redruth, where they recognised the signs of copper precipitation and set up a works (C 1869). However, Henry Kenroy states that sometime around the mid-eighteenth century the extraction of copper had been accidentally discovered at Cronebane when a shovel had been left in the outflow (Kenroy 1751). A chain of stone-lined oblong pits were built and iron bars were placed onto suspended wooden beams within them to attract the copper. After frequent agitation by scraping, the iron was eventually dissolved, the water was turned off and the copper mud shovelled out of the pit to dry in heaps (Argall May 1906).

The precipitation of copper salts was not new technology. It had been practised in mining areas across Europe working suphuritic ore bodies from the sixteenth and seventeenth centuries including Agordo in Italy, Waldeck in Germany and Rio Tinto in Spain. What is beyond doubt is that Cronebane witnessed the first practical application of this process in the British Archipelago. It soon caught on in the neighbouring Wicklow mines, where at Ballymurtagh in 1787 Captains James Jones and William Penrose (Welsh and Cornish respectively) were experimenting with placing low grade pyritic ores into mine water, comparing the strength of the resulting cupreous liquid with that observed at Parys Mountain. Nearby Ballygahan had decided to calcine the ores prior to washing, the water from the washing floors was directed into settling pits and then run onto iron scrap. Cronebane's copper pits were noted to have been making copper well in September 1787. The resulting precipitate was shipped from the Port of Wicklow to Liverpool (MS 16,304, NLI). Precipitation was also in use at the Parys Mountain Mines, Anglesey, at this period and was 'reintroduced' to Cornwall (where it had never been turned to practical account), by a return miner from the Cuban copper mines who set up plant on the Great County Adit in Gwennap in 1854 (Schwartz forthcoming 2012).

By the mid nineteenth century the cementation process in use at the Avoca mines had been much

improved from that described above, Smyth remarking on the plant at Tigroney and Connary, where mine water was led through a series of wooden launders inclined at angles of 10º or 12º interrupted at intervals by a hutch. At Tigroney, the launders were swept down with brooms every night and morning into the hutches, while Connary swept theirs daily. The Tigroney method yielded precipitate containing 50-60 per cent copper, that of Connary 43-54 per cent (Smyth 1853, 386-387).[10] Argall notes that the precipitation plant at Cronebane had disappeared before his time, but that Connary's was still in operation and he described this in detail (Argall July 1906). The old precipitation pits had indeed been replaced with gently inclined wooden launders twelve to eighteen inches wide and around nine inches deep, into which scrap iron to a depth of three inches was placed. The mine waters, pumped to surface, were first conducted into settling cisterns where ochre and grit was deposited, and then run through the launders. Wooden settling hutches (pits) five feet by 10 feet and around six feet deep with a capacity of up to 1,500 gallons, were sited just below the launders about every 200 yards. Every twelve hours the water in a section of launder was turned off revealing granular deposits of copper coating the iron that were easily brushed off and the iron raked over (evidence that Connary eventually copied Tigroney's twice daily brushing regime, proven to have yielded a precipitate with a higher copper content). Then the water was turned back on with full force, washing the precipitate in suspension into the hutches until they were full and the water then prevented from entering. After some twelve hours, when the precipitate had settled at the bottom of the hutch, the water level was lowered via plug holes to within four inches of the settled precipitate and the whole process repeated.

The launders were cleaned out quarterly, as were the hutches. The harvested precipitate was then passed through a sieve to remove any fragments of scrap iron and scales of metallic copper, the latter of which was added to the sifted precipitate. At some mines, like Connary, the precipitate was dried at low temperature by being regularly turned on cast iron plates over flues through which heated gases passed, prior to being placed in barrels and sent to Swansea for smelting; Argall recalled the startling appearance of the hirsute Connary 'dry-house man' whose exposure to the copper precipitate for over forty years had resulted in his moustache, forelocks and hair around his ears turning green! At other mines the precipitate was sundried before being packed, or barrelled in its wet state.

As the copper content of the water running through the launders decreased, so the tendency for ochre to be deposited on the iron increased, and this was made worse by a sluggish stream of water which halted the precipitation process. Either increasing the velocity of the water by inclining the launders more or by installing stair-like structures to speed up the water falling over the iron scrap and to aid oxidisation of the ferrous salts, copper was once more precipitated, but as a harder metallic substance that sometimes had to be chiselled off the iron. Finally, the mine water flowed lengthwise into four large settling ponds, 50 feet by 100 feet, where ochre was deposited and the waters clarified (Figure 4).

In 1873 the Cronebane mine was being worked by the Associated Mine Company which owned both the land and the mineral rights. Prior to 1872 this company had leased the mine to Williams and Co. that had relinquished it that year. The complicated nature of the mineral leases of Tigroney and Cronebane at this time are the probable result of a schism within the Williams family caused by a feud that erupted between John Michael Williams (1813-1880) and his uncles and cousins. This resulted in a legal case in 1862, after which their intertwined business interests were re-divided to enable the grandsons of old John Williams (1753-1841) to go their respective ways (Barton 1970, 19). At sometime prior to 1872, the estranged cousins of John Michael appear to have obtained control of the Associated Irish Mine Company (*FJ* 1872) and decided to work the mine themselves.

Argall and his father in law, George Oates, remained at Cronebane, working for one half of the Williams family, while the neighbouring Tigroney sett remained under John Michael Williams' control and was managed by Captain C.F. Williams (Mineral Statistics, 1873 and 1874). Tigroney commanded the main adit (Deep Adit) into which most of Cronebane's waters drained from Mosey Adit (later known as Cronebane Deep Adit) down Copse Shaft and into the Tigroney sett. Argall knew from repeated analyses of the mine waters that Cronebane mine was furnishing its principal copper content, which did not matter when the two setts were being worked by the same company. But times had changed and after convincing Captain Oates, Cronebane's Manager, of this fact a demand was made on the Tigroney company for a share of the profit from Tigroney's precipitation plant in the Avoca Valley. This was 'turned down hard' by Cornish Agent, Samuel Uren, and Captain Williams.

Undeterred, Argall planned to implement a system of underground cementation. Although he acknowledged that the waters could not be as thoroughly treated as they were at surface plant, his reasons for deciding to commence underground cementation were probably twofold. Firstly, he stated that he believed better results were possible with the rich, clear, warm, cupreous waters and where the cementation would be of the soft granular kind, easier to detach from the iron scrap. But more importantly, had he decided to use surface precipitation plant, this would have entailed diverting water that flowed from Mosey Adit, down Copse Shaft and out through Tigroney's workings. This would have diminished the volume of cupreous water available to Tigroney for precipitation purposes and would undoubtedly have caused problems. By removing the copper in solution wholly within the Cronebane sett and not reducing the volume of water flowing into the neighbouring sett in the least, it was difficult to see how Tigroney could object.

Captain Oates was nonetheless obsessed that underground precipitation might lead to some complication with Tigroney, and

[10] Frederick Roper, who visited Connary during his research for the 1842 Children's Employment Commission, noted what he termed an 'ingenious contrivance' set up to capture precipitate of copper from water pumped from the mine. It was received into a series of wooden troughs filled with bits of old iron and copper pyrites and the liquor received into a reservoir. But he noted that it was not particularly profitable.

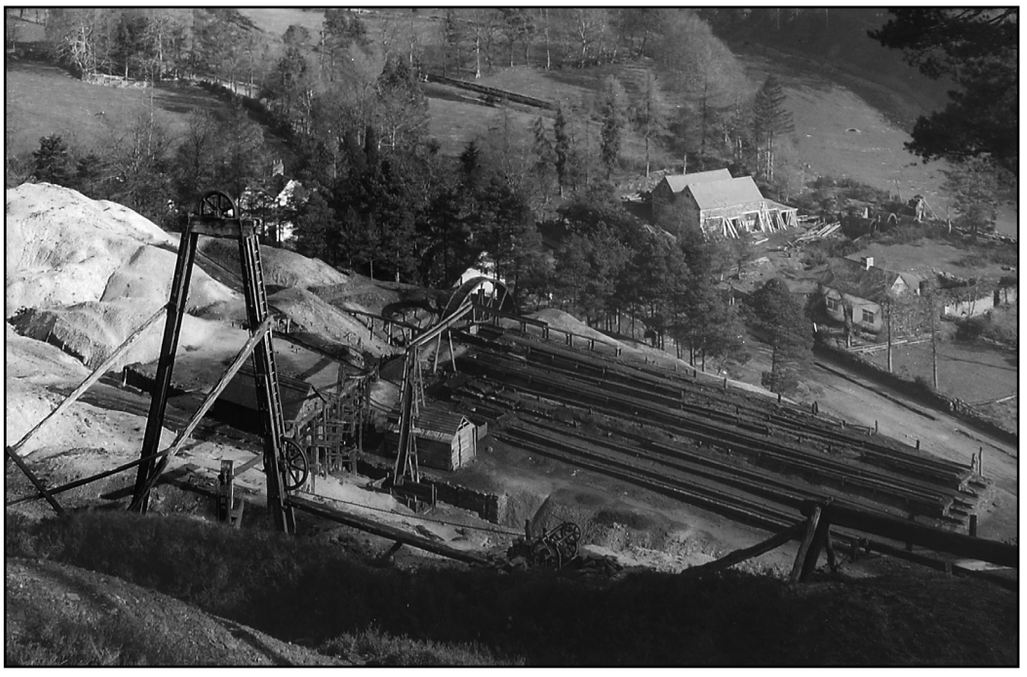


Figure 4. Series of inclined precipitation launders at Ballygahan Mine, West Avoca, late nineteenth century. This plant (bottom right) was similar to the surface cementation works described by Argall at the eastern Avoca mines. The Poole Collection, Courtesy of the National Library of Ireland.

presumably did not want this to be the spark that ignited simmering hostilities between the two sides of the Williams family. Sensibly, he wished to steer clear of any internecine strife, for the Williams were, after all, a dynasty that he knew could easily scupper a man's career if he fell foul of them. (This did not happen in Oates' case, as he took the Manager's job at the Williams-run Nantymwyn lead mine in Wales when he left Avoca). He and Argall cautiously decided to build just 100 feet of test launders in an unused and unventilated part of the far end of the main drainage adit (Mosey Adit) as far away from the boundary with the Tigroney sett as it was possible to go. The cupreous waters were conveyed in a pipe to a launder filled with scrap metal that was carried forward at a slight inclination until the floor of the level was reached, then the launder was returned along the floor (Figure 5). Argall was delighted:

> The precipitation was simply wonderful, the precipitate assaying nearly 90% copper. The result I soon learned was due to the clear warm water that was collected near its source in the mine, as compared with the cold muddy water, often laden with ochre that fed the surface precipitation plant. Well, the full plant was then ordered in and in a few months was operating satisfactorily (Rickard 1922, 10).

However, the cause of a mysterious accident not long afterwards in an unventilated 600 foot long cross-cut threatened to close the mine and to completely scupper his plans. 'Following a triple holiday, an explosion took place, burning two men rather painfully,' recalled Argall. 'An explosion in a metal mine so alarmed the Chief Mining Inspector that he wired us to leave everything as it was, pending his inspection.' Argall, however, started his own investigation. He had often noticed gas bubbles rising through the clear water in the launders, so he collected and tested this gas, relating how one night he:

> … crawled without a light into the cross cut to where a hole went up in the roof and there collected a wash-bottle full of the air. On reaching my laboratory I began and ended my investigation by holding a light to the mouth of the flask; I had a real first-class explosive mixture in it. (Rickard 1922, 10).

The gas was hydrogen. When the Chief Inspector, Mr. Dickenson of Pendelton Manchester, arrived, Argall demonstrated his findings to him and the pair entered the cross-cut with Clanny lamps.[11] These were provided by the Inspector who gave Argall his first instructions in the use of safety-lamps and formulated rules for the inspection of the 600 foot cross-cut. Thereafter, a duly appointed fireman with a Davy lamp had to inspect the workings daily before the men were permitted to enter.

Argall then proceeded to build precipitating launders for 2,000 feet along Mosey Adit from the Magpie Shaft that intersected it at 200 feet below surface. At intervals, suitable hutches for collecting the copper precipitate in the form of shallow winzes lined with cement were constructed, out of which the clear water was pumped prior to brushing the metals in the launders, or cement lined cross cuts, the mouths of which were built up with brick and cement to a height of about four feet and into which the water carrying suspended precipitate was lifted by a hand pump. At first the irons were brushed daily, but it soon became apparent that it was better to only brush the upper section of the launder system twice weekly as this created a higher grade precipitate. In one abandoned station of the Boundary Shaft, forty tons of pig iron in boxes were exposed to the action of the mine drainage for far longer. They were cleaned up monthly and never touched between clean-ups. 'The copper was therefore obtained in coarse crystals,' wrote Argall, 'and of great purity' (Argall July 1906). But the lower portion of the launder system still required daily attention to dislodge the

[11] The Clanny Lamp was the brainchild of physician, William Reid Clanny (1770 -1850), an Irishman from Bangor, Co. Down, who migrated to Sunderland where he developed a lamp in 1813 used by coal miners.

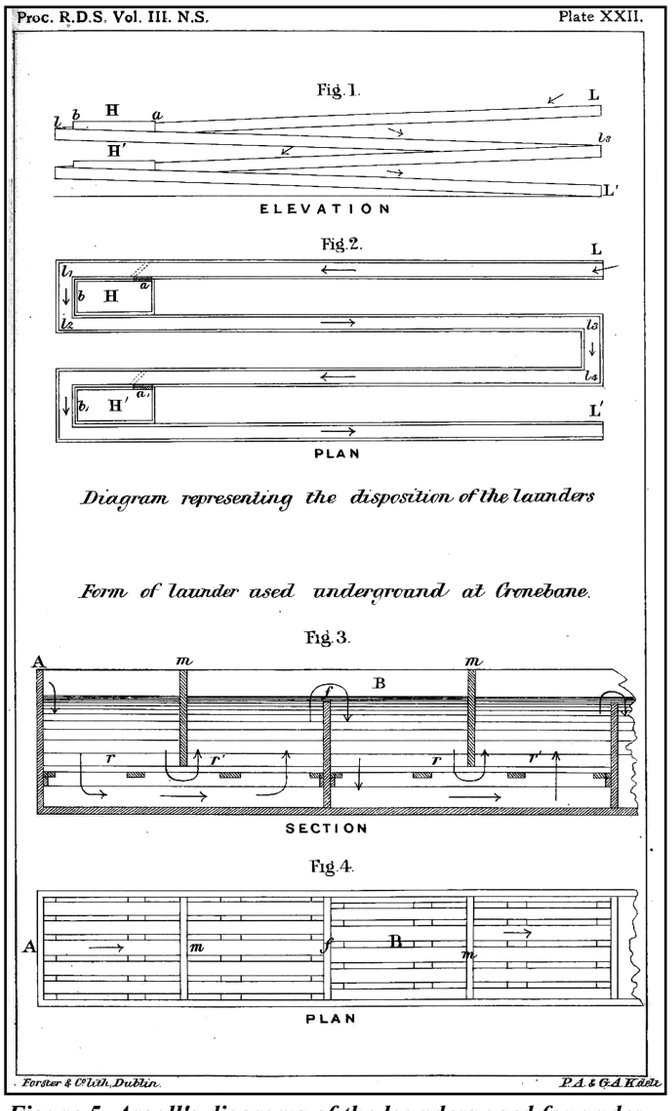


Figure 5. Argall's diagrams of the launders used for underground cementation at Cronebane, compared to those in use at surface plant on nearby mines such as Connary. Published in the Scientific Proceedings of the Royal Dublin Society, Vol. III, 1883.

ochre accumulation, one of the drawbacks of underground precipitation, where it was very difficult to greatly increase the fall of the water onto the scrap iron. Argall discovered that regulating the intensity of the flow of water or trying to precipitate the ochre in settling tanks beforehand made no difference.

Another problem arose in transporting the pig iron into the workings and the precipitate out. Most of the available space in the narrowest workings was taken up with the launders and some of the levels were crooked and too small to accommodate car-tracks, so the work was therefore effected by hand barrows, an onerous and time consuming task. Argall devised an ingenious system, brainchild of his father in law Captain Oates, to speed up the process: the monorail. This was a cast iron metal box capable of holding 800 lb suspended beneath two wheels that ran on a rail of 1 1/8 inch taut steel cable supported by a series of saddles protruding from supports placed close to the roof of the tunnel. The monorail, the first in the world to be used underground, could be easily pushed along by a man and was a great success (Figure 6).

Argall also improved upon the machinery used to lower the scrap metal down into the workings. On the upper adit (the Old 33 later known as the Cronebane Shallow Adit), a Cornish horse-whim (on Old Whim Shaft) with two buckets was being utilised to lower the cast-iron. Argall saw that:

> … if a brake was applied the horses might be eliminated. I got out a design for a brake on the top of the vertical whim 22 ft. from the ground, with rods and levers to the shaft-collar. The manager finally approved the design, but discarded the lugs I had provided to keep the brake-band from rising. The brake worked nicely on the evening it was finished. The next morning we had snow and ice, and in lowering the first bucket of iron, a lump of ice caused the brake-band to lift and slip off the friction-blocks, with the result that the bucket and 1200 ft. of steel-wire rope, the second I ever saw, went down the shaft. I believe it took a week to clean up the wreck. (Rickard 1922, 11).

Luckily no one was injured and after this initial problem was remedied, the apparatus gave great satisfaction and he patented it. Argall later wrote a paper in collaboration with G. A. Kinahan, district surveyor of H.M. Geological Survey, on the copper precipitation process at Cronebane, read on 19 June 1882 to the Royal Dublin Society and published in their proceedings the following year (Argall and Kinahan 1883).

SWANSEA: SMELTING METROPOLIS

Argall was just twenty five when he left the Cronebane Mine for Swansea, south Wales. Swansea, taking advantage of good anchorage on the Lower Tawe and its proximity to the high quality coal of the south Wales coalfield, was at its zenith as the recipient of various ores for smelting from every corner of the world. Here Edward Andrew Parnell set up the Stannic Company plant for the application of his innovative patents for recycling tin plate scrap. [12] In February 1879, Argall became the manager on a four month trial there. Tin and copper matte-smelting was also carried on to some extent and puddling-furnaces and a steam-hammer formed another part of the plant. The original Parnell process aimed to remove the tin from the scrap in a hot solution of sodium sulphide, evaporating the spent liquor, roasting to produce tin oxide and sodium sulphate and then smelting the tin oxide in Cornish furnaces. The iron scrap was heated in the puddling-furnaces and beaten out into blooms under the steam-hammer. Parnell intended to sell recycled block tin and iron and tin-plate blooms to the tin-plate works across the valley.

Whilst at Stannic, Argall was presented with many challenges. He had enrolled on a metallurgy course at Swansea, and soon discovered Parnell's system to be defective. The tin and the iron proved to be 'cold short' (a reference to metal that is brittle

[12] *London Gazette*, 27 August 1876, notes a patent under his name for 'an improved mode of utilizing tin-plate scraps or clippings and waste articles made of tin-plate'.

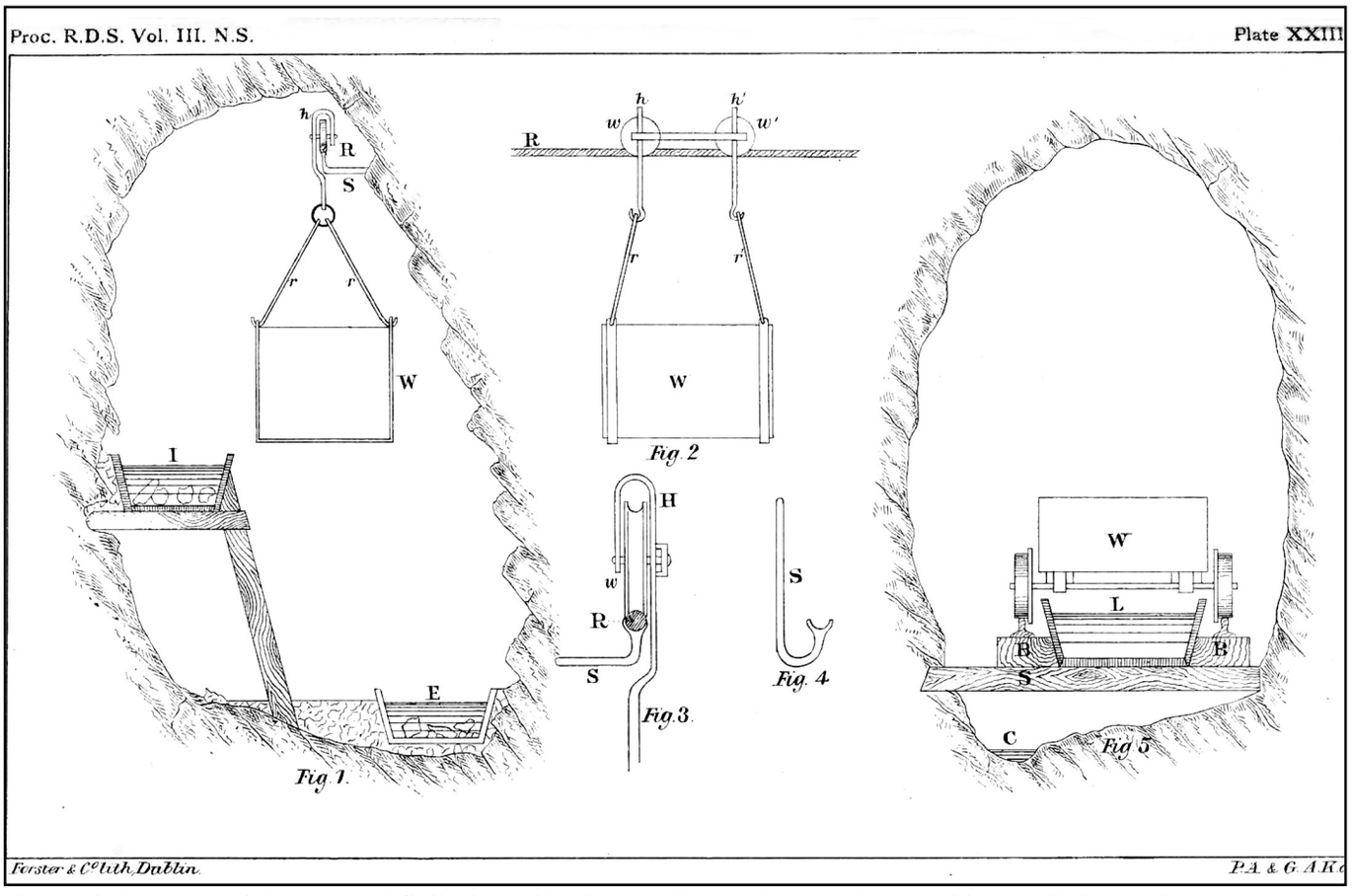


Figure 6. Diagrams of the monorail (left), devised by Captain George Oates and invented by Argall, designed to transport scrap iron and precipitate in Cronebane Mine through the narrowest workings, was the first such system to be used underground in the world. Elsewhere in the mine (shown right), the launders were placed between the usual wagon rails. Published in the Scientific Proceedings of the Royal Dublin Society, Vol. III, 1883.

below its recrystallisation temperature). The tin could only be sold for a price per ton well below standard tin as it was unfit for plating, and the iron was unsalable except for its use as a desulphuriser during lead-smelting. 'At the time I took charge of the works no one had ascertained what was the exact trouble with the tin,' recounted Argall, 'though considerable money had been spent in complete analyses of the refined tin'. On entering the refinery one day Argall noticed the wily Cornish refiner, John Uren, struggling with what looked like a very tough slag. On enquiring about the nature of the object he was trying to pull out of the furnace, the Cornishman remarked, 'I don't knaw. I have been thirty years smelting tin and I never saw no such stuff before… if I was one of they there chemists I'd assay this devilish stuff and not fool with the block tin'.

Argall took the hint, secured good samples, chilled them and soon discovered that the metallic substance was mostly tin sulphide reduced from the sulphate left in the tin oxide. He then determined the amount of sulphate present in the batch of oxide that was ready for smelting, added lime to correct it, and smelted a dozen samples, testing each button and finding every one best-grade tin. But Argall sought John Uren's opinion:

> I had worked through the night and our refiner was late in arriving. I placed all the buttons in a ladle and poured several test-bars on the marble slab. When John arrived he nicked and tested each bar and said, "It's best Banka, where did you get him?" (Rickard 1922, 13).

Argall replied, 'It is our tin scientifically smelted'. He had discovered that sulphur rendered tin unfit for plating and remedied a defect in Parnell's process. On the strength of this discovery he emerged from a directors' meeting with a year's contract in his hand and a fifty per cent rise in wages, with the caveat that he maintained the tin up to the grade of Banka (99.9 per cent tin) in the future. With the assistance of Uren, this was achieved.

Another of his achievements was improving the process of removing tin from scrap iron, by dipping the metal into a weak solution of lime chloride before feeding the de-tinned scrap to the puddling-furnace. This gave a higher recovery of iron in blooms free from tin which was volatilised as chloride. This was sold to the tin-plate works, rolled into plates and covered with refined tin, thus realising Parnell's ideal. [13]

ANTRIM, AND A WIDER WORLD

After a year and a half, Argall's health was compromised by the ever-present sulphur fumes at the Stannic works and in June 1880 he decided to return to Ireland with a glowing reference

[13] Parnell's business was liquidated in 1882, LG 1882.

from Parnell. He accepted the management of the Glenariff Iron Ore and Harbour Company in County Antrim (PRONI MSS). The supervision of the extensive mines of aluminous iron ore, ten miles of railway and the fascinating geology of the Glen kept him busy for a year, during which time he published a paper entitled, *The Tertiary Iron Ore Measures, Glenariff Valley, County of Antrim*, that was read before the Royal Dublin Society on 11 April 1881 and published in their Proceedings of that October (Argall 1881).

In 1881 Cornishman, Thomas Rickard, Consulting Engineer to the Duchy and Peru Mining Company, Cornwall, and the father of T. A. Rickard to whom Argall gave his first job as mine manager some years later (at the Union Gold Mine, Calaveras County, California), offered him the management of the mines that worked the great Perran iron lode. This was in the parish of Perranzabuloe, close to Argall's paternal ancestral home. 'So in 1881 I found myself mining zinc-blende with siderite gangue, hand-sorting the coarse ore and wondering what I would do with the fine, of which my predecessor left a large tonnage for good measure', noted Argall, who remained there until 1883, recalling that the mine was very hot.

He then worked for a year in London as manager of the Barking Metal Works which specialised in antimony smelting and refining, until the sudden failure of Richards, Power & Co. in 1883 closed the works. Lord Penzance, who had the largest holding, having been misled by Richards, Power & Co., refused to continue operations and the company was wound up. Argall returned to Cornwall to pump out the Old Duchy Peru mine, just purchased by Brown Bros., of St. Austell.

It was then that Thomas Rickard recommended Argall to the Kapanga Gold Mining Company in New Zealand, that was working a gold mine at Coromandel across the Hauraki Gulf from Auckland, a mining area with strong Cornish connections (Downey 1935; *DSC* 1867; Cyclopedia Company Ltd, 1902) [14]. The company, set up in about 1863, had started out well (*DSC* 1865). But an extraordinary general meeting had been called in late 1883 to discuss the poor returns of their mine and it was agreed to send out an experienced manager from Britain to ascertain and report on the true value of the property (*S* 1883). That man was Argall and he sailed for Wellington per the *British King* in 1884. Argall notes that the Kapanga was a specimen-gold mine and the most disappointing that he ever operated: 'I got the tail end of one small pocket and insufficient funds to find another'.

Following some mine examinations in France, he was then offered the superintendence of a group of mines in Sonora, Mexico: the Los Bronces and Animas mines in the Barranca district. The company operated under the name of the Silver Queen United and he remained there almost a year. Argall arrived to find a concentrating mill under erection and no water with which to operate it, and indeed very little ore either. He procured boilers, steam-pumps, and about three miles of pipe, unwatering three or four mines without filling the reservoir, but finally got started and made very irregular runs because of the many shortages of ore and water. Realising that the company had not obtained title to the property and that its finances were in poor condition, Argall left at the first convenient opportunity and travelled back to London before the crash came.

He once more returned to Ireland, serving as consulting engineer to the Mountcashel Iron Ore Co., in Antrim, Ireland, where he built a concentrating mill of 200 tons daily capacity to recover hematite pisolites from aluminous gangue. The plant was a success. In the same year (1886) he was appointed consulting engineer to the Société Anonyme de Plomb D'Asperieres, operating silver-lead mines on the river Lot, near Capdenac, Aveyron, in the Midi-Pyrénées region of France. A large concentrator had been erected against Argall's previous advice to the company and it did not treat the ore satisfactorily. The silver-lead, carrying an ounce of silver per unit of lead, was as soft as graphite and enclosed in quartz of the very hardest type.

This caused a lot of slime, a problem that was never solved, although the largest fixed Linkenbach tables Argall had ever seen had been put into commission to save the silver-lead in the slimes. To crush the quartz fine enough to liberate the galena so that a sixty per cent lead product could be made meant enormous losses, hence hand-sorting was pushed to the limit and a jig and table product sold, running high in silica. An English company struggled along with the enterprise for three years after which it was sold to the French, who operated it for several years more. Argall doubted if anyone ever made it pay. He was engaged there when he was offered the position of manager of the La Plata smelter in California Gulch, west of the City of Leadville, Colorado, in the United States. Like many Cornish and Irish migrants connected to the mining industry before him, in 1887 he made his way across the Atlantic, arriving in New York in May per the *Etruria.*

GO WEST! THE LEADVILLE EPISODE

His appointment as manager of an English-controlled silver-lead smelting enterprise at Leadville, Colorado, in March 1887 when he was just thirty three took him to the American West with which he became largely identified, becoming a naturalised citizen of the United States of America in August 1892 in Denver. The La Plata episode certainly tested his mettle, for the cut-throat competition between the Leadville, or 'mountain', smelters and those of the 'Valley', at Pueblo and Denver, when there was clearly not enough ore to maintain two large smelting enterprises, called forth all the resourcefulness of a strong character.

'Sulphide ores were coming in strong and the La Plata had no roasters', recalled Argall. Such refractory ores required new methods of treatment. Many mills across the western US at the time encountered similar problems; they could only process the richest ores and those without a high mineral content were put

14 The Kapanga area was some 29 acres in extent and had several claims including Kapanga, Scotty's, South & Blagrove's Claims. Kapanga mine had three steam engines at work that had been imported from England in 1866 at a cost of over £3,500. Henry Battens, a native of St Erth, Cornwall, erected New Zealand's first direct acting pumping beam engine on the Coromandel Gold Mining Company's property at Union Beach. It was later re-erected at the Kapanga Mine.

onto the dumps as it was unprofitable to ship them for treatment. At La Plata, Argall encountered blast-furnaces that were small and obsolete and the ore and charges were all handled by shovel and wheelbarrow. He soon realised that a large custom business was being handled at a loss and that the only option was to modernise or close. He requested $250,000 to re-build the furnaces, put in roasters and generally modernise the plant, which was refused.

> I confess to a feeling of relief when the directors decided to close-down the smelter and cut their losses. Nevertheless the night we blew down the furnaces was a trying one for me. It seemed like a metallurgical funeral. I patrolled the dump the whole night long, wondering if I had terminated a great industry that in other hands might have been profitable, or if I had rightly advised my company. A few days later this depression passed away with the full conviction that I had taken the proper course, and I have never since regretted my action (Rickard 1922, 19).

In the course of a few years other and better equipped Leadville smelters went out of business. Argall oversaw the sale of La Plata smelter to D. H. Moffat and associates. Pyritic smelting was introduced under the direction of W. L. Austin and was successfully continued under the management Franklin Ballou for several years. Argall served Austin in a consultancy capacity, designing dust-flues and condensing-towers ensuring the plant operated at considerable profit. His later attempts to introduce pyritic smelting in Colorado with Austin were unsuccessful and eventually the La Plata smelter, partly re-built and enlarged, was purchased by the American Smelting & Refining Company that dismantled it.

THE BATTLE FOR CYANIDATION: EXPERIMENTS AT DEADWOOD AND CRIPPLE CREEK

Five years later came his first contact with cyanidation, the process which made him famous. From 1850 to the early 1900s, chlorine had been the favoured lixiviate (leachate) for gold ores unresponsive to stamp mills (Lougheed 1989). Two processes were used. The first was the Plattner process, during which chlorine was fed into a leach tank containing a damp ore then washed several hours later with water to dissolve the gold chloride. The second was the barrel process, during which chlorine was added directly to agitated ore slurry. The solids were filtered and the gold values were removed with the liquor (Nesbitt *et al.* 1990).

However, the development of the MacArthur-Forrest process in 1887 changed the course of mineral processing and with it the world economy. Beginning in October 1887, metallurgical chemist John MacArthur and two physicians, Robert and William Forrest, secured a series of cyanide-related patents for the Cassel Gold Extraction Company of Glasgow, Scotland, that was formed in 1884 by Charles Tennant who had brought together several alkali makers to form the Tharsis Sulphur and Copper Co. in 1866 to take over pyrite mines in southern Spain (Checkland 1967). As the Tharsis Mines contained tiny components of gold, the Cassel Gold Extraction Company was registered on 15 December 1884 to acquire certain patent rights of Mr. H. R. Cassel, a New York metallurgist, who had helped to develop the chlorination process. [15] The process they developed recovered gold by leaching pulped ore with a solution of potassium cyanide and then with water, precipitating the gold on zinc or aluminium. The three men built a test plant and experimented on ores from around the globe. In 1889 they established cyanide plants in three of the British Empire's major mining centres to demonstrate and market their technique.

MacArthur-Forrest's process was first used commercially in New Zealand at the Crown Mines, Karangahake District, by the Cassel Gold Extraction Co. and also in Australia. But its use in successfully treating the low grade tailings of the famous Robinson Deep Mine in Johannesburg, South Africa, was pivotal. Cyanide has a natural affinity for gold, which dissolves in it just as sugar would in a hot liquid; it is more selective than chlorine especially with low grade pyritic ores, and crucially, was cheaper than the reagents required to produce chlorine. It revolutionised the South African gold mining industry that had been on the brink of disaster by making it possible to cheaply treat the deeper pyritic ores, as well as free-milling concentrates, residues, and tailings dumps (Gray and McLachlan 1933). Between 1890 and 1893 the production of gold recovered by cyanidation in South Africa increased by a thousand times to 10 tons per year (Fivaz 1988).

The first plant using the MacArthur-Forrest Process in the USA was erected at the Crestone Mine, 125 miles southwest of Denver in about 1890. However, cyanidation was slower to catch on in the USA where the ore bodies were quite different in nature from those in South Africa and where chlorination was commonly used. Here it met a rather chilly response, a 'practical miner' expressing his doubts thus in 1892:

> California is spotted with the wrecks of crank mills and processes that were going to revolutionize the business - going to, but didn't. The fact is, these patent processes ... put money in the pockets of inventors, and still more [in the pockets] of promoters. When they show me an honest miner who has got rich through this cyanide process, I may take some stock in it. (Mining and Scientific Press 1892).

Argall was one of the doubters. He had heard and read much about cyanidation, but he admitted,

> … for some time I considered it one of the humbugs. It was in the hands of people who did not inspire confi-

[15] Arthur and Forrest were granted their English Patent for their process in October 1887 (Patent No. l4174). Their application for a patent in the USA (Patent No. 403302) is dated November, 1887, but the patent was not issued until 14 May 1889. This was for the extraction of gold and silver from their ores by a solution of potassium cyanide which contained not over eight parts of cyanogen per thousand. Later they were granted a patent on the precipitation of gold and silver from cyanide solutions by zinc, preferably in a filaform or threadlike condition and on the use of caustic alkali to neutralize the acid in the ore.

> dence and who advertised the requirements of the process as a few old tubs, some mill-tailing, a chunk or two of cyanide, and a handful of zinc shavings. (Rickard 1922, 20).

However, along with the likes of Charles W. Merrill, nicknamed 'Cyanide Charlie', and Charles Butters, Argall became one of the chief advocates of cyanidation in the US, was at the forefront of its development and was crucial in proving its commercial viability there (Spence 1970, 240-242).

Not long after his arrival in Colorado, Argall had been accepted as a member of the Colorado Scientific Society, serving as its President in 1906. The membership of this organisation read like a roll call of the leading lights in the Western American mining world, and included several prominent Cornishmen renowned for looking after their own (the fabled 'Cousin Jack' network). Dr Richard Pearce, deemed one of the 'most eminent metallurgists in the world at the time of his death in 1927', was a founder member, and the society also counted among its ranks one of the world's foremost mining specialists: the Cornish-American, Thomas Arthur Rickard, a friend of Argall (Rowse 1967, 324-330; Spence 1995, 102-103). This group of eminent mining men met to discuss and debate issues related to geology, mineralogy and ore-dressing techniques and also participated in field trips to various mines and mills. Argall presented numerous papers on ore dressing techniques and cyanidation to this esteemed peer group, and, as a member of the American Institute of Mining Engineers as well as being a Fellow of the Geological Society of America, he published numerous books and papers (these are listed in the sources section at the end of this paper). [16] His patient metallurgical experiments made him a recognised pioneer of the cyanide process, and, as Rickard stresses, 'in the controversies between dry and wet crushing, between roasting and non-roasting, between sliming and non-sliming, he played a prominent and useful part' (Rickard 1922, 36).

Argall took up a position as consulting metallurgist to the MacArthur-Forrest Company and in about 1893 was instructed to rectify a failing gold mill at Deadwood that had been built between 1891-1892 in the Black Hills of Dakota by men from the Hill City tin mines. 'The ore could not be leached,' remarked Argall,

> … because dust and sand were treated together in the tanks and there was too much dust. Those in charge had imported a patent pulverizer from Grenoble, France, believing "fine dust" [for it was a dry-crushing machine], essential to good extraction'. (Rickard 1922, 21).

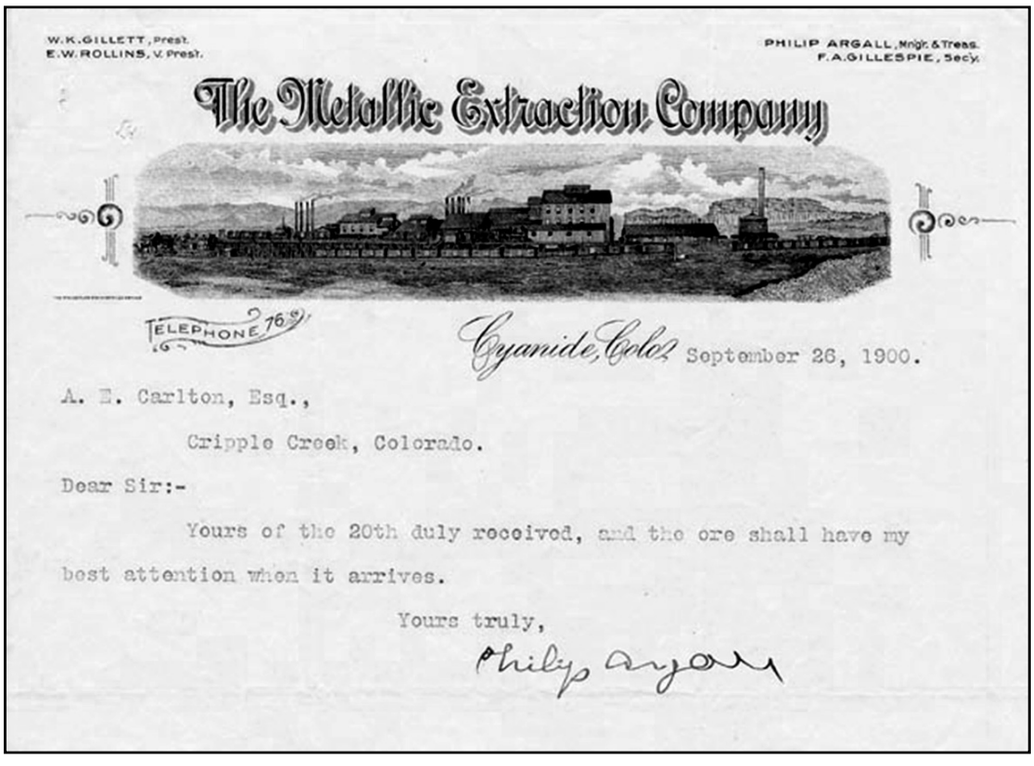
Argall substituted rolls for the pulverisers and with a few other changes the plant operated successfully. However, he reached the conclusion that slime and sand should be treated separately, so he designed a special machine for separating the dust from the sand in dry crushing and used V-boxes to affect the same object in wet crushing, thus anticipating what would later become standard practice in the industry. He experimented with crushing in alkaline solutions, separating the slime or dust from the sand and treating each separately. His dust separator apparatus was patented in 1904 and was used widely in Western Australia and elsewhere. To treat the dust, this was first moistened and run through a briquetting machine, the bricks stacked, dried, and roasted in the same way as common building-bricks are made, then broken up and cyanided. The briquetting and roasting had the effect of providing a porous material and the extraction obtained from the roasted brick was so much better than that obtained from the sand, that it led to an investigation which subsequently caused Argall to introduce roasting as a preliminary step to cyanidation. The experiment made on the dust of the Deadwood ore gave remarkable extractions of ninety six to ninety eight per cent. The successful modifications Argall made to this plant resulted in it being the first of its kind in the world.

In January 1894 he travelled to Cripple Creek in Colorado to investigate the failure of the first cyanide plant in that district, which became known as the Brodie Mill. Rather than being metallic gold in quartz like that mined on the famous Californian Mother Lode, Cripple Creek's ore was in the form of gold tellurides: sylvanite and calverite. The conventional stamp mill in which ores were crushed and the gold amalgamated with mercury was almost useless in refining the sulpho-telluride Cripple Creek ores. Telluride is one of the very few elements that will chemically combine with gold and is leachable by cyanide but it takes a considerable amount of time for the minerals to be completely dissolved, while the two percent of sulphur present in the ores added to the difficulties facing metallurgists. Argall attacked the Cripple Creek ore problem, 'with all the intensity of the Celtic temperament'.

He found the problems at the Brodie to be similar in nature to those he had encountered at the mill in Deadwood. The charges in the tanks could scarcely be moistened as there was so much talc and clay in the dry-crushed ore. Argall pointed out the cause of the trouble and rectified it when enlarging the plant, which operated successfully for a year or two and was again enlarged. Argall left the Brodie Mill with a capacity of twenty five tons per day and as the treatment charge on an ounce ore was $15 per ton, the company needed to realise every cent of the value of its ore. Within three years, this thirty-ton-per-day mill was expanded to 400 tons per day, the largest in the Cripple Creek District.

In 1894 he was tasked with overseeing the construction of the Metallic Works at Cyanide, Colorado (Figure 7). The Moffat interests were building the Florence and Cripple Creek railroad and desired to have a large reduction plant near its terminal. Argall was sent for and found the directors prejudiced against cyanidation, because 'the ore would not leach'. Determined to prove them wrong, he planned to revolutionise the process by putting into practice what he had learnt at Deadwood - roasting the slimes before cyanidation. He demonstrated this process to the directors with a pocketful of the roasted cupels, a small plate, and a bottle of water:

[16] Argall was also a member of other learned societies including the Royal Irish Academy and the Mining & Metallurgical Club, London.


W.K.GILLETT, Prest.
E.W.ROLLINS, V.Prest.

PHILIP ARGALL, Mngr. & Treas.
F.A.GILLESPIE, Secy.

The Metallic Extraction Company

TELEPHONE 76

Cyanide, Colo. September 26, 1900.

A. E. Carlton, Esq.,

Cripple Creek, Colorado.

Dear Sir:-

Yours of the 20th duly received, and the ore shall have my best attention when it arrives.

Yours truly,

Philip Argall

Figure 7. This rare letter-head, signed by Argall in 1900, records his position as Manager and Treasurer of the Metallic Extraction Company. The Metallic was the world's first mill for direct treatment of sulpho-telluride ores, a system invented by Argall to treat Cripple Creek ores. It was here that Argall introduced the eight hour shift, the first mill in Colorado to do so. By kind permission of Brian Levine, Mt. Gothic Tomes and Reliquary, Crested Butte, Colorado, USA.

> I poured water on the plate and set the cupels in it and in a few minutes the water was all soaked up by the briquettes and I added more and when the water rose to the rim of the briquettes and began to fill the bowls, the directors were satisfied, and a week later the Metallic Extraction Company was incorporated, and by June 1895 we were treating 3000 tons of ore per month. (Rickard 1922, 22).

During the winter of 1895 Argall began roasting Cripple Creek ores. He modified a multitubular drier and roasted and leached several lots of twenty five tons each. Shortly afterwards he purchased Colorado's first Ropp roasting-furnace, but later designed his own multitubular roaster. The 400-ton-per-day Metallic Extraction Company mill at Cyanide included massive dryers and roasters, rows of roll crushers, and a cyanide vat structure the size of a football field. In this test-mill Argall made his first experiments in amalgamating and cyaniding the coarse roasted Cripple Creek ore. The Metallic plant was the world's first for direct treatment of sulpho-telluride ores. Mines throughout the Western US studied and copied it, and it attracted metallurgists from around the world:

> We then purchased all the oxidized ores available and treated them direct, but the recovery of gold from the roasted product was so superior that the roasting facilities were rapidly increased, and by the close of 1897 we had a capacity of 10,000 tons per month. This was a pioneer plant in the direct treatment of sulpho-telluride ores. Engineers and metallurgists came from various countries to study our methods, more particularly the roasting feature. We had several visitors from Kalgoorlie, notably from the Great Boulder Perseverance mine. (Rickard 1922, 23).

Argall achieved success by experimenting and constantly modifying his methods: 'By the time the roasting process was fully developed, it became apparent that we were placing the cart before the horse. In roasting the telluride, coarse gold, in shots and grains, was formed commensurate with the size of the telluride particles in the feed, pieces often too large to be dissolved in the time available for the leaching process'. To avoid the formation of large particles, Argall crushed the ore finer and also placed riffles in the tailing-sluice. The riffles were only partially effective in that they collected the 'metallics' and also some of the unroasted sulpho-tellurides. The answer lay in grinding the ores even finer, but that would have generated more dust and required a larger bag-house and a substantial increase in the treatment cost.

Argall then experimented with making available all the coarse gold possible during the roasting process and recovering this through amalgamation of roasted ore in Chilean mills using a weak cyanide solution instead of water, avoiding the drying of the ore, dry crushing and dust-loss. This had the advantage of keeping costs down, as a bag-house was not required. He had discovered that ore crushed to pass a ¼-inch round-hole screen when roasted gave almost perfect extractions by amalgamation and cyanidation. The directors were satisfied that a completely new plant should be constructed based on the strength of their metallurgist's new discoveries and decided to set up a new plant at Cañon City with a capacity of 15,000 tons per month. When that was in successful operation, they planned to remove the machinery from the Metallic to the new plant and ultimately have a mill capacity of 25,000 tons per month under the new process at an estimated treatment cost 50 per cent below the cost at the Metallic plant.

A branch of the Florence & Cripple Creek railroad was begun in late 1898-early 1899 to Cañon City to accommodate the new

plant. However, this was suspended when the Moffat interests optioned their railway and the Metallic plant to those controlling the Midland Terminal railway, a rival line for Cripple Creek traffic. Their option was taken up and the Metallic works passed to another company, but Argall remained in charge until the close of 1900, in fulfilment of his contract. The new owners expressed no interest in building new works and scrapping or removing the plant they had just purchased for $600,000, so Argall refused to renew his contract. The new owners were the United States Reduction & Refining Company, which was capitalized at $13 million by New York investors and set up by two men from Philadelphia - Spencer 'Speck' Penrose (of Cornish descent) and Charles L. Tutt. They had gone into business together and achieved great success with their barrel-chlorinating ore mill, the Colorado-Philadelphia Reduction Works at Colorado City, designed by their partner, Charles Mather MacNeill of Illinois, to treat Cripple Creek ores. This company sought to monopolise the milling of Cripple Creek ores by forming a mill 'trust' or 'combine', in which chlorination was the dominant feature. The Metallic Mill operated for about six months after Argall left, closed down, caught fire while being dismantled in 1904, and burned to the ground. As Argall recalled somewhat bitterly:

> …financial affairs often upset the best-laid plans of metallurgists, so because of financial backing, and not because of merit, the chlorination process reigned supreme for about six years. (Rickard 1922, 25).

BROMINATION V CYANIDATION: GOLDEN CYCLE AND STRATTON'S INDEPENDENCE

Argall was no fan of the bromination process either that was at that time championed by New York metallurgist, Henry Rennel Cassel. He saw the process trialled at the Telluride Mill that became known as the Golden Cycle Mill at Colorado Springs and considered cyanidation to be cheaper and wholly preferable (Figure 8). Cassel's mill had been erected to treat Cripple Creek ores by leaching with bromine solution in open vats, displacing the bromine in the filtrate with chlorine and recovering the bromine for re-use. The evolution was from open vats to covered vats, covered vats to revolving barrels similar to those used at that time in the chlorination mills and lastly, to straight chlorination in the revolving barrels. Perhaps doubtful of the efficacy of this process, stockholder, John T. Milliken of St. Louis, employed Argall to look into the process at the time of the trial run. Argall pointed out in a letter to him what he considered to be the weak points and advised him to not exercise his option, which advice was followed.

A few years later, in 1904, the plant went into the hands of a receiver; Argall, then at Goldfield, Colorado, received an urgent telegram requesting him to come at once to New York for a consultation. Milliken had handed Argall's letter on the shortcomings of the Cassel bromine process to the company and the directors desired his advice. Argall examined and reported on the plant, placed a valuation on it, and advised that cyanidation be introduced. The large shareholders, running shy of further

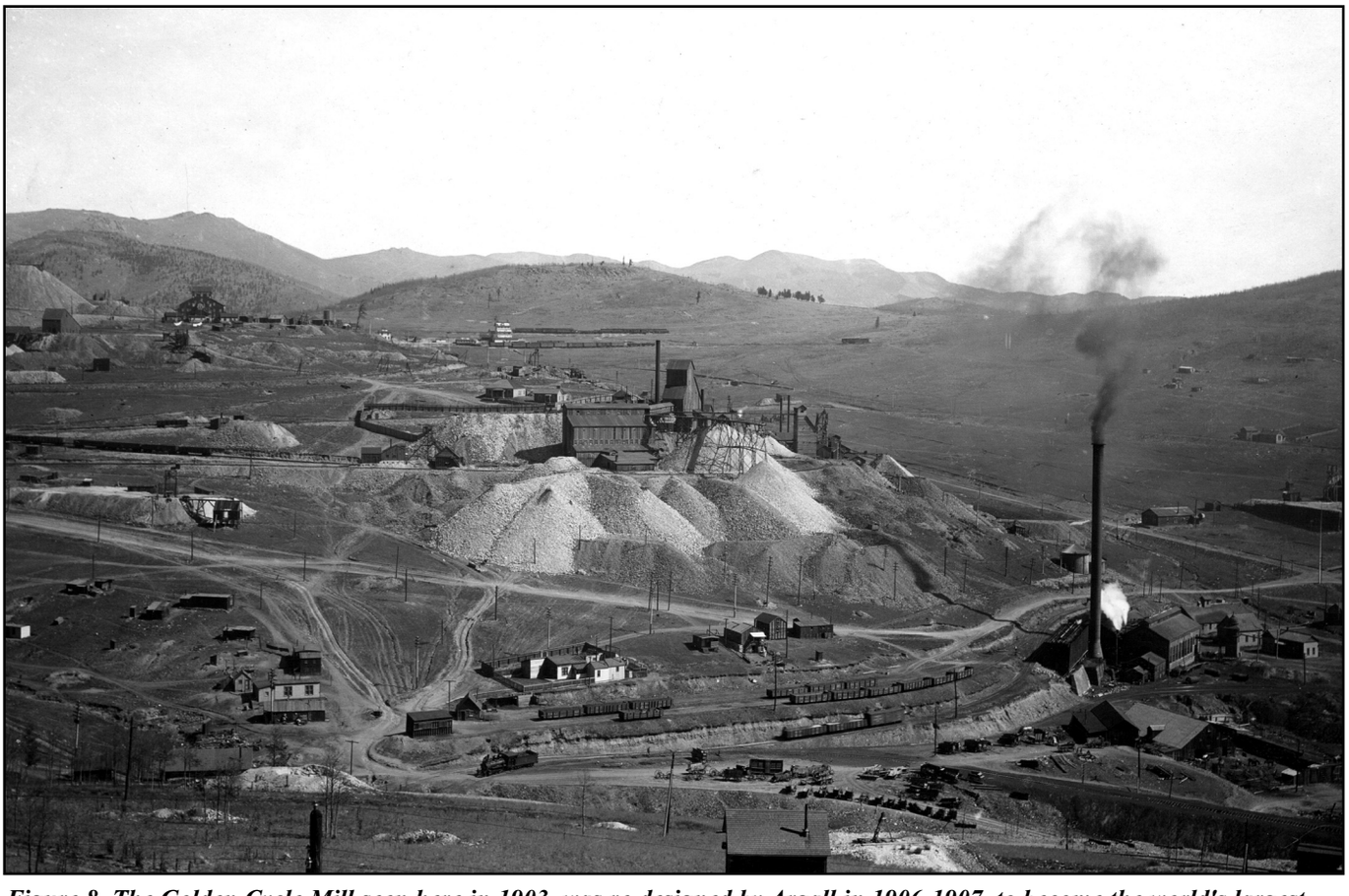


Figure 8. The Golden Cycle Mill seen here in 1903, was re-designed by Argall in 1906-1907, to become the world's largest dry roasting cyanide mill. United States Geological Survey, ID Ransome, F. L. 526.

investment, held some meetings and finally decided that they had had enough. 'The money lost in that venture was about $800,000,' recalled Argall. John Milliken kept faith with Argall's observations on the plant and in 1906-1907 authorised him to design a new state of the art Golden Cycle Mill at Colorado Springs to treat Cripple Creek ores. This became the world's largest dry roasting cyanide mill.

Argall was ultimately to be proven right in his judgement as to the effectiveness of cyanidation. He maintained his interest in the process, insisting that it was bound to supersede chlorination in the treatment of Cripple Creek ores, as the process was so much simpler and so much cheaper. Between 1903 and 1907 he presented frequent lectures and contributions to the technical press about cyanidation and served in a consultancy capacity, particularly in connection with the Dolores mine in Chihuahua, Mexico, where he solved the problems of old tailings that would not leach, filter in a press, nor settle for a decantation. This was cured by the addition of two pounds of sulphuric acid per ton of dry slime. Argall considered solving this problem to have been 'one of his best day's work'. In autumn of 1905 he oversaw the field-work of the Zinc Commission appointed by the Government of Canada to investigate the zinc resources of British Columbia and test the ores to determine the best commercial process for beneficiating them. This included the Great Sullivan mine. It took the greater part of 1906 to complete these ore-tests and prepare the report and maps (Haanel 1907). The work was well received.

His big breakthrough came in November 1906. He was working in the Arizona desert when he received a cablegram from London offering him the position of consulting engineer to the celebrated Independence Mine at Cripple Creek that had been built into a formidable enterprise by the late Winfield Scott Stratton (1848-1902) (Figure 9). Cripple Creek's first millionaire, Stratton had sold the Independence in 1899 for an astronomical ten million dollars. Argall was tasked with making a prompt investigation of the best means for treating the huge tailings dumps there. This was vindication of his methods, since his protagonist, Cassel, had built a small testing-plant using an electro-cyanide process and the Cassel filter process at the mine, but it had not been deemed successful. Much money had been spent and nothing accomplished. Argall immediately laid himself open to criticism by stating that low grade ore could be treated by his methods on the mine for about one-fourth of the cost charged by other operators, recalling wryly that he '… certainly received [his] full share of attention from the people that fail to advance with the times'.

His campaign was crowned with complete success. A cost of $1.51 per ton and an average extraction of 74.57 per cent on dump ore was a remarkable achievement at the time. The cyanide process was finally judged to be the most efficient for recovery from Cripple Creek gold ores and he became manager of the enterprise in 1906. He was able to report that in the twenty years from 1893 to 1913 he had seen the cost of Cripple Creek ores treated by wet methods fall from $15 per ton to $1.38. By 1911, all the chlorination mills were gone.

Figure 9. Stratton's Independence Mine, Cripple Creek, Colorado, where Argall was appointed Consulting Engineer in 1906. His work here finally ensured that the cyanidation of telluride ores superseded the chlorination process. Authors' Collection.

DENVER CONSULTANCY AND THE AVOCA SYNDICATE

Argall retired from active mines to Denver, where he formed a consulting partnership with his sons, Philip Henry jnr. and George Oates Argall in February 1905. The firm were consulting engineers to the Independence and other big mines, as well as smaller concerns including the Graphic Mine, at Magdalena, in New Mexico. Ever a candidate for the saying, 'science is a specialised form of common sense', Argall continued to move with the times and became interested in the use of flotation for concentrating ores, a field he was experimenting in until his death in 1922. At the Graphic Mine he encountered a very bad mixture of sulphides and iron oxides consisting of sphalerite intimately blended with magnetite, pyrite, pyrrhotite, specularite, galenite and chalcopyrite in a lime and tremolite gangue. By careful experimentation he managed to achieve a ninety five per cent recovery on this mixed zinc ore by developing the Ozark Flotation Process, based on a film-suspension process originally devised by Henry Ellsworth Wood of Denver in 1912 [17]. Designed especially to concentrate these ores, it was patented by W. Sydney Stevens of Magdalena.

Argall also kept a close eye on the state of the mining industry in his native Ireland, and was involved in an attempted revival of mining at Avoca in the early twentieth century. He was convinced that there was plenty of mineable ore left in East Cronebane, particularly within the old Magpie section which he had thoroughly explored in 1875-8. Here, the pyrite under the gossan was disseminated as a coarse sand in a clay gangue impervious to water. This undisturbed zone he believed to be very rich in copper. He induced some London capitalists to reopen this zone in 1900, forming the Avoca Syndicate under the management of Mr. E. H. Davies, a well known London Consulting Engineer, in 1902. Argall had the records of hundreds of assays made during the mid-1870s, as well as his original surveys. Several pits were sunk at places he selected under promise of three per cent copper; the ore found, however, averaged nearly four per cent copper, about one quarter of which was soluble.

However, instead of mining the ore in mass (the ore body was about forty feet wide) and treating it by modern ore processing methods with which Argall was familiar in the USA, the new operators followed the practice of the previous centuries, in attempting to dig out the fine seams and stringers of high-grade in the shale and sending the ore to Swansea for reduction. On that basis the enterprise proved unprofitable and after two years the Avoca Syndicate sold their interests to another London Company: the Electrolytic Copper Co. Ltd. 'A steam-shovel proposition was tackled with pick and timber, and the result was inevitable,' noted Argall somewhat scathingly:

> … London capitalists have long looked at Ireland as the Jews did on Nazareth - a place out of which no good could come. The promoters failed to raise the necessary funds to properly explore the property, while it fell to my lot to add to my former somewhat varied experiences a close parallel to the New Testament character who undertook to journey from Jerusalem to Jericho. (Argall July 1906).

The later twentieth century extensive opencast excavation of the Magpie section of the Cronebane Mine proved the veracity of Argall's observations.

ARGALL'S LEGACY

Argall died in Denver on 18 March 1922 aged sixty eight and was interred at the city's Fairmount Cemetery. His obituary described him as 'a world authority on metallurgy' (*WP* 1922). The cyanide process he perfected and made profitable remains the dominant process for gold extraction more than a century after it first attracted his attention. For this reason he was inducted into the US Mining Hall of Fame in 1996 for his 'practical work to commercialize gold cyanidation [which] changed the course of the gold industry' (Mining Hall of Fame Inductees' Database). During his glittering career, Argall received many accolades and awards, including a gold medal and forty guineas in 1903 by the Consolidated Gold Fields of South Africa through the Institution of Mining and Metallurgy for a paper on the mechanical treatment of ore by the dry process; he was also a Gold Medallist of the Institute of Mining Metallurgy, London.

Yet, this modest man saw an event in the spring of 1899 to be his finest achievement: the introduction of the eight hour shift at the Metallic Extraction Company's mill, implemented without even consulting his directors. Cripple Creek had been periodically plagued by bitter and violent labour strikes and disputes, with miners demanding better working conditions. The Metallic was the first mill in Colorado to adopt the eight hour shift and Argall believed passionately that this practice was better for all concerned:

> … The introduction of the 8-hour working-day in Colorado mills… led to better work in time, to a better class of workmen, and a greater tonnage handled per man, in a word, to the elevation of our workmen and the lowering of the working cost. (Rickard 1922, 34).

This speaks volumes about the character of this largely self-taught, practical Cornish-Irishman, who learnt his trade the hard way, as a young man in the mines of Avoca, Wicklow.

PRIMARY SOURCES

National Library of Ireland (NLI), Avoca Mines Papers, MS MS 16,304, MS 16,337.

Public Record Office of Northern Ireland (PRONI), Glenariff Iron Ore and Harbour Company in County Antrim, D2977/30.

[17] In 1912 H. E. Wood described his method of concentration, by the surface tension of water alone, in a paper read before the American Institute of Mining Engineers. In common with other metallurgists, he had noticed that dry particles of sulphide minerals are "good swimmers". Previous gravity work had tried to drown them. He had also proved that oxides were easily wetted. He devised a machine in which the dry-crushed ore was fed in a thin stream from a vibrating plate onto a current of water. An impetus was given to the surface by small water-jets. By retarding the current the gangue was made to sink, while the film of sulphides remained on the surface.

SECONDARY SOURCES

Argall, P. H., 'Notes on the ancient and recent mining operations in the east Ovoca district. With plates', *Journal of the Royal Geological Society of Ireland*, Vol. **V**, 1879, pp. 150-164.

Argall, P. H., 'Notes on the Ancient and Recent Mining Operations in the East Ovoca District', *The Scientific Proceedings of the Royal Dublin Society*. New Series, Vol. **II**, 1879, pp. 211- 225.

Argall, P. H., 'Notes on the Tertiary Iron Ore Measures, Glenariff Valley, County Antrim', *Scientific Proceedings of the Royal Dublin Society*, Vol. **III** (iv), 1881, pp. 151-168.

Argall, P. H., 'Gold-bearing quartz', *Colorado Scientific Society*, vol. **4**, 1893, pp. 331-336.

Argall, P. H., 'Origin of ore deposits', *Colorado Scientific Society*, 1893, vol. **4**, pp. 353-354.

Argall, P. H., 'Nickel. The occurrence, geological distribution and genesis of its ore deposits', *Colorado Scientific Society*, vol. **4**, 1893, pp. 395-421.

Argall, P. H., 'Pyrite smelting process', *Engineering Magazine*, vol. **7**, 1896, pp. 78-84.

Argall, P. H., 'Extraction of gold from low and medium grade ores', *Colorado State School of Mines, Biennial Report*, 1896, pp. 39-46.

Argall, P. H., 'Geology of Cripple Creek district', *Colorado Scientific Society*, vol. **5**, 1898, pp. 43-45.

Argall, P. H., 'Cyaniding telluride ores', *Mining Industry*, vol. **6**, 1898, pp. 368-379.

Argall, P. H., 'Sampling and dry crushing in Colorado', *Mining Reporter*, vol. **45**, 1902, p. 270, (cont. abstract from paper read before Inst. Mining and Metallurgy, London.)

Argall, P. H., 'Chlorination vs. cyanidation', *Engineering and Mining Journal*, vol. **78**, 1904, pp. 821 and 1021.

Argall, P. H., 'Cost of Mining' and 'Cost of chlorinating Cripple Creek ores', in T. A. Rickard (ed.), *The Economics of Mining*, New York, 1905, pp. 342-347 and 356-357.

Argall, P. H., *Mining and Scientific Press*, 19 May 1906.

Argall, P. H., 'The Recovery of Copper from mine-Drainage', *Mining and Scientific Press*, 28 July 1906, pp. 111-113.

Argall, P. H., 'Steps in cyanidation', *Colorado Scientific Society*, vol. *8*, 1907, pp. 323-347.

Argall, P. H., *The Colorado scientific society. A toast...* Denver, 1907.

Argall, P. H., 'Rock oxidation at Cripple Creek', *Mining and Scientific Press*, vol. **96**, 1908, pp. 883-886.

Argall, P. H., 'Ore deposits of Magdalena, New Mexico', *Engineering and Mining Journal*, vol. **86**, 1908, pp. 366-370.

Argall, P. H., 'Reducing mining costs and increasing profits', *Engineering and Mining Journal*, vol. 90, 1910, pp. 1251-1252 and Mining Science, vol. **62**, 1910, pp. 567-568.

Argall, P. H., 'Metallurgical processes in Colorado', *Mining and Scientific Press*, vol. **100**, 1910, pp. 35-40.

Argall, P. H., 'Cyanidation of Cripple Creek ores', *Mining and Scientific Press*, vol. **101**, 1910, pp. 804-805.

Argall, P. H., 'Milling methods at Stratton's Independence', *Mines and Minerals*, vol. **32**, 1911, pp. 319-320.

Argall, P. H., 'Colorado metallurgical progress', *Mining and Scientific Press*, vol. 104, 1912, pp. 78-81.

Argall, P. H., 'Milling Sulpho-Tellurides at Cripple Creek', *Mexican Mining Journal*, 1912, p. 27.

Argall, P. H., 'History of cyaniding Cripple Creek low grade tellurides', *Mining and Engineering World*, vol. **36**, 1912, p. 915 and *Banker and Investor Magazine*, 1911, p. 368.

Argall, P. H., and Kinahan, G.A., 'Notes on Recovery of Copper from its Solution in Mine Drainage with Special Reference to the Wicklow Mines, *Scientific Proceedings of the Royal Dublin Society*, Vol. **III**, 1883, pp. 302-328.

Checkland, S.G., *The Mines of Tharsis*, London 1967.

C - *Cornubian*, 21 May 1869.

Cowman, D., 'Mining Scams? Three Examples from Wicklow', *Journal of the Mining Heritage Trust of Ireland*, **3**, 2003, pp. 9-12

Cyclopedia Company Ltd, *The Cyclopedia of New Zealand*, Christchurch, 1902, pp. 487-488.

DSC - *Daily Southern Cross*, 12 October 1865; 30 October 1867.

Downey, J. F., *Goldmines of the Hauraki District,* Wellington, 1935.

Fivaz, C. E., 'Presidential Address: How the MacArthur-Forrest cyanidation process ensured South Africa's golden future', *Journal of the South African Institute of Mining and Metallurgy*, vol. **88** (9) 1988, pp. 309-318.

Geological Survey of Great Britain, *Mineral Statistics of the Kingdom of Great Britain and Ireland for the Year 1873*, London, 1874, p. 201.

Geological Survey of Great Britain, *Mineral Statistics of the Kingdom of Great Britain and Ireland for the Year 1874*, London, 1875, p. 203.

Gray, J. and McLachlan, J. A., 'A History of the Introduction of the MacArthur-Forrest Cyanide Process to the Witwatersrand Goldfields', *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, June 1933.

Haanel, E., *Report of the Commission to Investigate the Zinc Resources of British Colombia and the Conditions Affecting their Exploitation*, Ottawa, 1907.

Hull, E., Memoirs, *Explanatory Memoir to Accompany Sheets 138 and 139 of the Map of the Geological Survey*, Dublin, 1888, p. 25.

Kenroy, H., 'Of the Copper-Springs in the County of Wicklow in Ireland', *Philosophical Transactions of the Royal Society of London*, vol. **XLVIII**, 1751, pp. 280-282.

Kinahan, G. A., 'On the mode and occurrence and winning of gold in Ireland, *Scientific Proceedings of the Royal Dublin Society,* Vol. **3**, 1883, pp. 263-285.

LG - *London Gazette*, 2 June 1882.

Lougheed, A. L., 'The Discovery, Development, and Diffusion of New Technology: The Cyanide Process for the Extraction of Gold, 1887-1914', *Prometheus*, Vol. 7:1, 1989, pp. 61-74.

MS - *Manx Sun*, 20 August 1870.

McArdle, P., 'the Wicklow Gold Rush', *Journal of the Mining Heritage Trust of Ireland*, **3**, 2003, pp. 15-19

Mc Ardle, P., Gold Frenzy: The Story of Wicklow's Gold, Dublin, 2011.

Mining Hall of Fame Inductees Database, accessed 7 August 2011:

http://www.mininghalloffame.org/

Mining and Scientific Press, 21 May 1892, p. 376.

Nesbitt, C. C, et al, 'Determination of the Mechanism of the Chlorination of Gold in Aqueous Solutions', *Industrial and*

Engineering Chemical Research, **29**: 8, 1990, pp. 1696-1700.
Pawley-White, G., *A Handbook of Cornish Surnames*, revised edition, Redruth, 1981.
Report of the Royal Cornwall Polytechnic Society, 1878, p. 29.
Rickard, T. A., *Interviews with Mining Engineers*, San Francisco, 1922, pp. 5-39.
Rowse, A. L., *The Cornish Miner in America*, Redruth, 1967.
S - *Star*, 6 December 1883.
Schwartz, S. P., *The Cornish in Latin America: 'Cousin Jack' and the New World*, Dublin, forthcoming 2012, p. 344.
Smyth, W.W., *Records of the School of Mines and Science Applied to the Arts*, Vol. 1, part III, On the Mines of Wicklow and Wexford, London, 1853.
Spence, C. C., *Mining Engineers and the American West: The Lace Boot Brigade, 1849-1933*, Yale, 1970.
Spence, C. C., *British Investments and the American Mining Frontier 1860-1901*, Moscow Idaho, 1995.
Woodrow, A., A History of the Conlig and Whitespots Lead Mines, *British Mining* No. **7**, 1978.
WB - *West Briton*, 26 February 1847; 15 March 1850.
WP - *Washington Post*, 29 March 1922