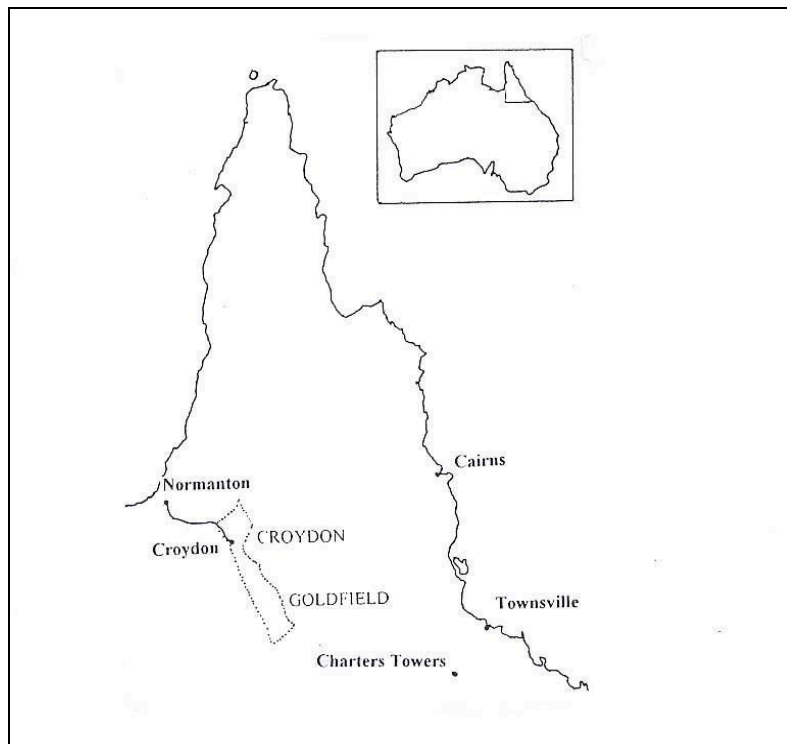


Underground Gold Prospecting Techniques on a late 19th – early 20th Century Queensland Goldfield

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Most mines these days tend to large scale workings on massive ore bodies, preceded by intensive drilling campaigns. Today's miners miss out on the excitement of reef mining as experienced around the turn of the 20th Century – those moments of anxiety when the quartz pinched down to nothing in the drive, the mineral cut out in the face, or worst of all, when the next blast revealed a blank wall of rock as the lode faulted in directions unknown. Because of the patchy nature of the ore-bodies this applied in particular to gold production. It is the intention in this paper to examine the response of miners to such problems. Croydon, a small goldfield in North Queensland will be used to illustrate the prospecting theories and practices that were applied. This examination should shed light on approaches adopted by small mines generally, as opposed to the 'best practice' often described for larger mines on major goldfields.

Map 1: *Croydon Goldfield*



Croydon, discovered in 1885, peaked in the 1890s and like most Queensland goldfields was in decline by 1920. It was a medium-sized field for Queensland, producing 770,000 fine ounces of gold (approx. 24,000kg)¹ by 1930, and was financed by a mix of local and British capital. A promising beginning was cut short when the richest reefs in the town area disappeared at relatively shallow depths in 1890. The centre of mining moved to nearby Golden Gate, the most successful of a number of 'outside' mining camps clustered within a 50km radius. The puzzles posed by Croydon's disappearing reefs, and those problems which normally beset quartz vein ore-bodies such as patchy values and faulting, gave particular urgency to underground prospecting on the field.

Lacking X-ray vision, miners could develop their theories based on experience, or use those coming out of the new science of geology. One of the most important was the dominant geological theory of the True Fissure Lode.² This mythical beast was based on quartz ore-bodies occurring in softer 'formation' in fissures in the rock. Ideally the fissures had well-defined walls, went down into the rock on an even grade to considerable depths, and persisted for some length across the countryside. Otis Young notes that in the U.S. this concept originated in the extrusion theory of lodes: that ore-bodies were extruded into the rocks from below. The assumption was that the ore-bodies must 'live down' to their parent magma and that mineral values would persist at depth. He also noted the competition to this theory by others, emerging from the science of geology between 1850 and 1890.³ In Queensland, it persisted into the 20th Century. In fact, quartz lodes can pinch and expand in their 'formation'; peter out altogether at depth or along the strike; be faulted or change direction so the continuity of dip or strike is destroyed; and have wildly varying gold values.

The expectation of an even grade of dip was a trap for unwary miners, who might confidently sink a shaft to catch a reef some distance from its cap (its outcrop on the surface) on the understanding that they would meet it at a certain depth. In the meantime, the reef had faulted further down, changed dip to a steeper angle, or cut out altogether. They might meet it in a form quite unlike its appearance closer to the cap, or go down at a different angle, and decide it wasn't the right reef.⁴ If it lacked those well-defined walls, they were in real trouble. Miners debated the latest results of exploratory shafts and drill-holes in the deep ground, trying to decide which changes in rock indicated formation and which ones meant a return to country rock. Plant's Deep Shaft on Golden Gate was reported as being in formation so often that the fissure should have

been 150 feet (45 metres) wide. If what mine-owners found didn't conform to expectations, they might look until they ran out of money.⁵ Many even tried to fit stockwork-style⁶ ore bodies into the 'fissure' model and went hunting for the 'reef' at depth.

The 'real' reef could be distinguished from other quartz veins encountered at depth if it had plenty of water, indicating a large ore-body channelling water from the surface. It would carry sound from higher workings, have the right angle of dip, and have similar types of quartz and formation to those in mines closer to the cap. It was vitally important to identify the correct reef, as the miners would then explore it by drives. 'Real' reefs were also long, so a great deal of effort was put into trying to link lines of reef together and searching for the bits in between, which they deduced must be hidden below soil, laterites or sedimentary rock.

Geologists' theories were sometimes as unreliable as those of the 'practical miner'.⁷ One of the most expensive mistakes to hit Croydon was the idea of the 'intrusive bar of granite' which Government geologists decided had abruptly terminated the field's richest reefs.⁸ The miners thought it was a slide, that is, a fault, but of course the geologists' theory attracted the Government subsidies for testing. As a result a number of expensive holes were put down in places which accorded with the official theory, but with no success. It took until the 1980s to prove that the miners were right: they had struck a large reverse fault, and the reefs still have not been found at depth.

One geological theory that was welcomed by desperate miners was the Law of Faults. When you hit that hard rock wall, what next? Croydon had plenty of experience with faults, the prize going to the King of Wallabadah:

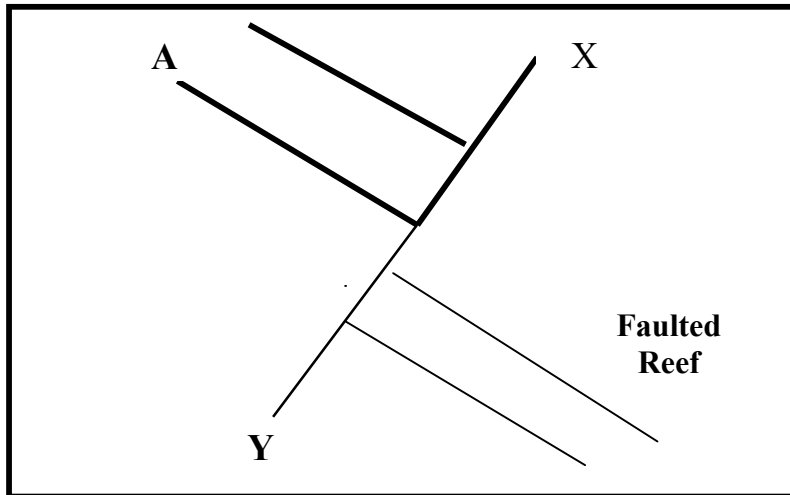
The Prayer of Jerry Campbell

Oh King! Oh, King of Wallabadah!
Oh, how I wonder where you are!
Your drops and slides and heads and feints
Would tire the patience of the saints!
For honour sake and fair renown
I mean to find thy Golden Crown;
If patience, health and strength will tell
I'll find thee if thou drop to h___⁹

Geologist Dunstan was enlisted to the cause and explained the 'law of faults' to the miners, helping them to map a series of breaks.¹⁰ The simple version of the Law of Faults was said to follow the lode according to the greater angle between the lode, when lost, and

the dip or strike of the fault¹¹ (see Figure 1). The complicated version (Figure 2) was said to be better, though others declared that there was no law of faults at all. Another idea was to study the way the reef bent just before the fault and follow that direction along the fault wall (Figure 3). Unfortunately some reefs didn't bend, or bent both ways.

Figure 1: Law of Faults



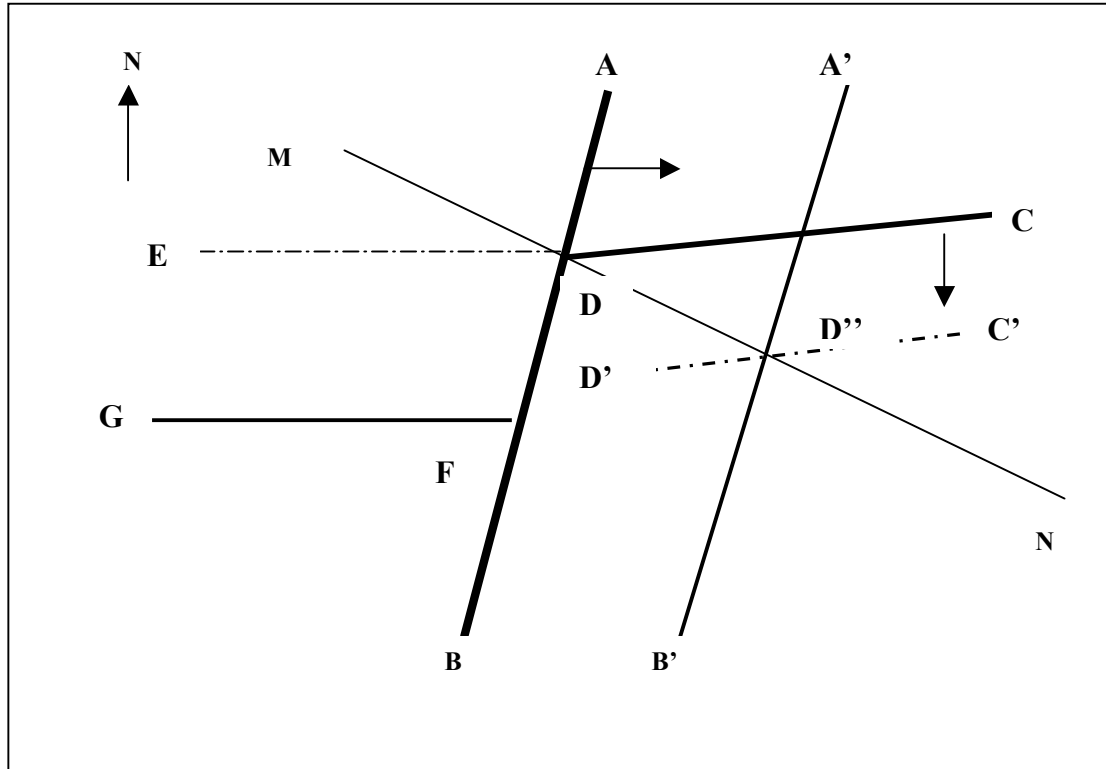
The angle ABY is greater than the angle ABX, so the reef should lie on the line BY rather than BX

The most erratic phenomena were shoots, patches of richer ore within the quartz. Nothing seemed to work to predict these. Kalgoorlie's 'regular lenticular patches' of gold-bearing ore were described as irregular in size and occurrence, and in Bendigo the only guide was that they were more likely to occur along the strike of its unusual ore-bodies, which were of quartz sandwiched between layers of bedded and folded rock. The ore tended to be richest in the centre of the anticlines.¹² Sinking to catch shoots in the deeper ground was a chancy affair, so it was important that decisions were based on some kind of evidence acceptable to the general public in order to attract finance.¹³ Barren patches in existing mine workings were treated in much the same way as pinching of the quartz: any change was good.

The most commonly used method to track down good ore was the indicator. Every field had some quirk associated with mineral occurrences, which was said to 'indicate' to the miner where the gold might be found. Geologists today would suggest that these might be controlling mineralisation. In Croydon, for example, graphitic granite was the key, or finding galena and pyrites in the ore, or layered quartz. The Golden Gate 10&11 S Block even reckoned it had 'gold-bearing stone without the gold'.¹⁴ Gympie soon learned to associate beds of 'black shale' with gold where they were intersected by quartz reefs. On Kalgoorlie, higher gold values were associated with

finer-grained pyrites.¹⁵ Unfortunately, miners sometimes used indicators from other fields, which proved rather unsuccessful. They could also be fooled by over-confident use of their own judgement. ‘Yellow mundic’ was an indicator of poor ore at Golden Gate until someone thought to sample it, with payable results.¹⁶

Figure 2: *Schmidt’s or Zimmerman’s Law of Faults*



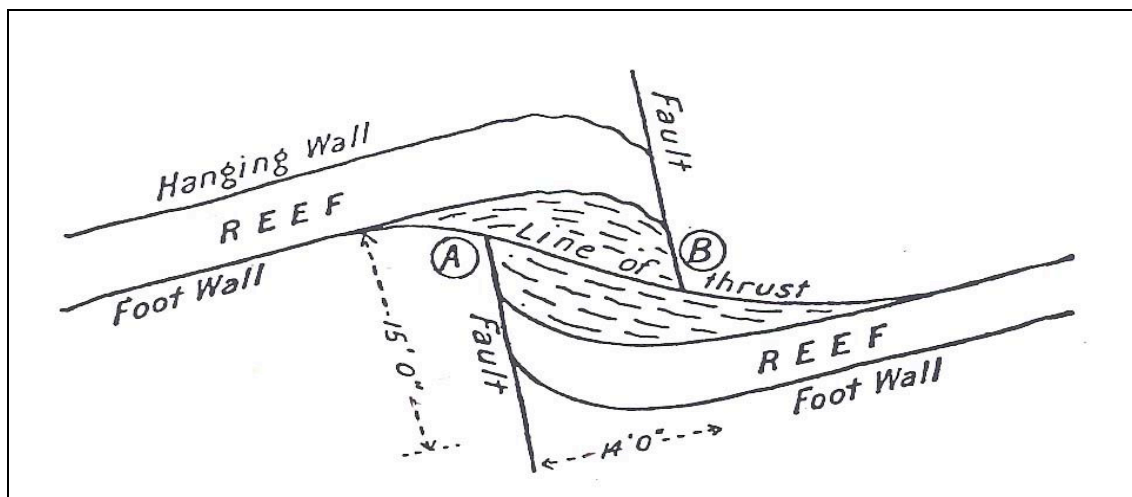
This law finds lodes laterally displaced by a fault. AB represents the strike of the fault. CD is a lode being driven on until it is lost at D. the strikes of the lode and the fault are reproduced by lines parallel to the real lode and fault, the same distance apart, to reproduce C' – D' and A' – B'. Where these lines meet is D''. Join D and D'' and prolong this line at both ends to produce MN. Put a line at right angles to AB at the point D, in the direction of the opposite wall of the fault. As this line DE falls below MN, the miner would go south along the fault and expect to cut the reef on the opposite wall of the fault at GF an unknown distance away.

Source: Le Neuve Foster, *A Treatise on Ore and Stone Mining*, Charles Griffin, London, 1910, p.92.

Even in the 19th Century, thorough sampling was being recommended for underground prospecting to guide further development and later, stoping. In a well run mine, development work such as shafts, drives, and cross-cuts into the walls would be put in well in advance of stoping to find the limits of the ore-body, and a careful sampling programme would test these workings at regular intervals so the value of the ore at any point in the mine could be ascertained. It was considered essential for those ore-bodies with indeterminate boundaries such as Kalgoorlie.¹⁷ Sampling was less helpful for gold-

bearing reefs because of their variability but, systematically used, could provide a useful plan of the workings to give a better idea of trends in mineralisation. Croydon miners did use sampling, mostly the drillings from the holes made for explosives. This would have horrified the sticklers for accuracy as it was impossible to recover all of the material from the holes and was a patchy method at best. The grab samples used were likewise condemned by the experts. Worse, many samples were panned rather than fire assayed; panning, even at its best, is hardly an exact method. There were two assayers in town capable of doing fire assays so panning was probably chosen for its cheapness. A few local mines appear to have tried systematic sampling but these were usually for large deposits of low-grade ore with low profit margins per ton. They required more careful monitoring to ensure profitability. Some managers were contemptuous of the whole procedure, trusting their own judgement, which may explain why a large well-developed block of 'poor' ore in Roger's Golden Gate when let on tribute crushed over 4 ounces per ton.¹⁸

Figure 3: *Following bend in the reef*



Bends in the lode showing the direction in which the lode is faulted, Golden Gate United Mine.
Source: B. Dunstan, 'Some Croydon Gold Mines', *Geological Survey of Queensland*, 1905.

Instead of systematic development using proper sampling methods, miners tried to dodge the expense and trouble by theorising their way to the gold, usually because of lack of capital. Most Queensland mines were expected to finance development and exploration out of profits, so the economics of small mines meant that they looked for shortcuts to the richer ore. There was nothing necessarily wrong with using geological theories to do this, but the theories could become fanciful. For example, one philosopher decided that Croydon's reefs were really dual or triple reef systems and a lot of money

was spent trying to prove it.¹⁹ Another decided that the richest deposits of gold in the town mines occurred where two reefs joined, a common belief in mining circles at the time. After spending £5,000 in prospecting, he found he was wrong.²⁰

Another shortcut was to watch what was happening in neighbouring mines. This was a logical way to proceed when prospecting at depth for the lode itself; Charters Towers and Gympie often used it.²¹ However using neighbours' work to predict shoots was trickier. Shoots appearing to trend into someone else's ground might be hunted for at great expense and with uncertain results. The Golden Gate 9 North chased a particularly rich shoot trending towards their ground and finally was able to celebrate a 9-ounce (280gr/ton) crushing that netted them £1,000. The champagne bottles had barely emptied before they had to pay £967 to their neighbours. The shoot had stopped short at the boundary.²² On Croydon, mining became a helter-skelter series of shafts and drives in whatever part of the ground was considered most promising from developments in a neighbour's workings.

Some relied on luck, such as the pair on the Sir Garnet reef who decided to sink until they 'found something'.²³ Unfortunately dumb luck was responsible for enough rich finds to encourage this type of behaviour. A hole dug for a windlass prop underground in the Golden Gate 5 South hit a 'nice reef' in what everyone thought was the footwall.²⁴ Cautionary tales from everywhere aggravated the problem; mining lore abounds with tales of abandoned mines taken over by a new party who found rich stone just a little further on. For example, Craven's Folly at Charters Towers was always before the minds of Northern mining men. A disregarded leader later proved to be a rich reef, encouraging mine owners to persist with unpromising lodes regardless of geological probability.²⁵ In other words, they gambled. Even the Under-Secretary for Mines wrote, after a particularly expensive and fruitless drilling campaign, 'The sums expended on prospecting have been ... resultless. There is more philosophy in the old digger's saying, 'That where the gold is, "there it is" than is generally conceded, and ninety-nine out of a hundred valuable discoveries have been made simply by chance'.²⁶ Religion may also have been resorted to but wasn't mentioned, apart from the Chinese investor who consulted the god of the local temple and was reassured that his choice had plenty of gold. It did – but mixed up in too much rock to be payable.²⁷

What of that indispensable modern prospecting tool, the diamond drill? Steam driven drills had been around from the 1840s and the diamond drill prospecting plant since about 1875.²⁸ They bored holes of 1 to 5 inches (2.5 - 12.7 cm) in diameter using a

diamond-tipped crown attached to a series of hollow rods. The rods retained rock cores that gave a profile of the rocks, and the water sent down to cool the bit flushed up drillings that could also be sampled. By 1906, they could drill 12 - 18 inches (30 - 45cm) an hour in hard rock.²⁹ Unfortunately they had their problems. A good water supply was essential as they went through 2,000 gallons (9,000 litres) a day. The crown could jam, the rods could break, and the results be of questionable value. For example, the rods could deflect by 200-500 feet (60-150m) horizontally in every 1,000 vertical feet (300m) and surveying the hole was difficult. The sample size was too small for patchy ore bodies and the technique too expensive for a large network of holes to compensate; even in a relatively well capitalised and technologically advanced field as Kalgoorlie there were complaints that results could be misleading.³⁰ In the 1890s a Croydon mine owner discovered it was actually cheaper to sink a shaft to the depth wanted, at £3,000 as opposed to the £4,000 to drill one hole, though by 1910 the costs could be half that.³¹ Drilling times could be much slower than expected; in 1888 one drill took five months to bore 100 feet (30m) of granite.³² By 1908 newer drills run by contractors were producing results at a cost that made them attractive (£1.2s.6d per foot instead of £3.7s.9d), but even then they were too expensive for large drilling programmes.³³ Drilling was therefore limited and could only be used to test geological theories and the results were, of course, subject to all the problems of interpretation according to the True Fissure Lode theory. Miners also pointed out the advantages of exploratory shafts: if you found something, you could open out on it immediately. Even the *Mining Standard* in 1910 said diamond drills were better for prospecting horizontally in the works than vertically from the surface.³⁴

In Queensland, the Department of Mines was responsible for introducing diamond drills for prospecting. Two generations of machines were purchased, in the mid 1880s and another set in 1889. After a series of disasters with accidents to the rods, coupled with poor and uneconomical performance, the Department regretted its decision and the 1890s Depression halted further experimentation.³⁵ This led to a reversion to prospecting shafts.³⁶ However there is no doubt that some of the prejudice against the drills was caused by their failure to find expected reefs in the deep ground of Gympie, Croydon and Charters Towers – a case of shooting the messenger.³⁷ The reputation of the diamond drill in Queensland gold mining was rescued by Mt Morgan, which used it with great success to prospect its ore-body at depth. The Under-Secretary for Mines wrote approvingly that the modern drill was clearly cheap and expeditious, and noted a ‘general tendency to restore the diamond drill to its rightful position as an aid to prospecting’.³⁸ The firm responsible, Gold Fields

Diamond Drilling Co., suddenly found itself in demand all over the state.³⁹ However, diamond drilling was more successful for prospecting massive or predictable and regular mineral deposits such as coal beds, deep leads and copper ore-bodies.⁴⁰

A cheaper alternative was the hand spring-bore or cable drill, powered by human muscle. A drill steel was raised by rope to the top of a 10-foot (3m) frame and dropped; the drill would be turned by the rope twisting slightly at each drop. They were used often on Croydon, for depths up to 50 feet (17m), though one was put down 150 feet (51m). Again, they tested geological theories. The most persistent user was Thomas Bennion, who over two years drilled 20 holes in hard granite to depths of 15 to 50 feet (4.5 to 17m), averaging 18 inches a week (45.7cm).⁴¹

The underground prospecting solutions tried on Croydon and other North Queensland goldfields sometimes seemed to have more in common with tea-leaf reading than science. This is because geology was not advanced enough to understand what was controlling gold deposition on any given field, and because information about the occurrence and behaviour of the ore-bodies was limited, particularly at depth. The latest technology, in the form of the diamond drill, and latest scientific theories could be unhelpful or actively misleading. Consequently miners resorted to theories that could be highly questionable. Lack of capital meant that miners relied on observation and experience rather than systematic and expensive techniques like the diamond drill or sampling programs of the kind recommended as best practice at the time.

Endnotes

¹ J.H. Reid, 'Report on the Croydon Goldfield', *Queensland Government Mining Journal*, vol. 36, 15 March 1935, p. 128.

² For official endorsement, see for example, Report of the Under-Secretary for Mines for 1901, where he describes the Lancelot mine as 'the truest fissure lode in the district' with 'splendid walls'. *Queensland Parliamentary Papers* [hereafter *QPP*] 1902, vol. 3, p. 261.

³ Otis E. Young Jr., *Western Mining*. University of Oklahoma Press, Norman, 1970, p. 8.

⁴ See for example, 'The Waratah Mine', *Croydon Mining News*, 12 November 1896.

⁵ For example, at Plant's Block, Bennion's Block, and Highland Mary Blocks, *Croydon Mining Record*, 14 July 1904, 12 August 1909, 1 July 1910.

⁶ Stockwork or stockwerke is an area of rock seamed by small veins of auriferous quartz. These ore-bodies are typically massive. That is, there is no clear strike or dip.

⁷ There was considerable rivalry in this period between the new mining professionals and the craft miners, which was sometimes expressed in rival theories. Bewick, Moreing and Co. criticised the 'rule of thumb mining manager of the sixties to the eighties' as 'theoretical' in the sense that they built on inadequate knowledge. *Croydon Mining Record*, 28 January 1909. For further information, see Jan Wegner, 'Language and power in nineteenth century mining: a view from North Queensland', *Journal of Australian Studies* No. 61, 1999, pp. 164-168.

⁸ W.H. Rands, *Croydon Gold Field*. Geological Survey of Queensland, no. 118, Brisbane, 1896.

⁹ *Croydon Mining Record*, 15 June 1905.

¹⁰ *Ibid.*, 17 July 1903.

- ¹¹ Clement Le Neuve Foster, *A Treatise on Ore and Stone Mining*, Charles Griffin, London, 1910, pp. 89-92.
- ¹² E. Davenport Cleland, *West Australian Mining Practice*, Chamber of Mines of W.A., 1911, p. 12; K.A. Cameron and W.M. Morgan, 'Some side-lights on the prospecting programme of Bendigo Mines Ltd and its subsidiaries', *Proceedings of the Australian Institute of Mining and Metallurgy*, no. 103, 1936, pp. 274-5.
- ¹³ See for example, the Empire Co., formed to prospect the '98' mine in order to catch a rich shoot thought to be trending in from its neighbour. *Croydon Mining News*, 9 September 1909.
- ¹⁴ *Croydon Mining Record*, 3 December 1903.
- ¹⁵ Cleland, *West Australian Mining Practice*, p. 12.
- ¹⁶ *Croydon Mining Record*, 3 March 1904.
- ¹⁷ Cleland, *West Australian Mining Practice*, pp. 11, 102-3, 137-8.
- ¹⁸ *Croydon Mining Record*, 20 February 1903, 12 January 1906.
- ¹⁹ *Queensland Government Mining Journal*, 15 December 1905, p. 646; *Ibid.*, 15 March 1909, p. 135; *Ibid.*, 20 April 1959, p. 266; *Croydon Mining Record*, 17 October 1902; *Croydon Mining News*, 1 July 1909.
- ²⁰ *Croydon Mining Record*, 22 April 1909, 18 November 1909, 13 May 1910.
- ²¹ See Report of the Under-Secretary for Mines, 1905 in *QPP* 1906, vol. 2, p. 1122; and for 1906, *QPP* 1907, pp. 1007, 1009.
- ²² *Croydon Mining News*, 10 December 1896.
- ²³ *Ibid.*, 28 February 1907.
- ²⁴ *Queensland Government Mining Journal*, 14 February 1903, p. 86, and 15 April 1912, p. 179.
- ²⁵ *Croydon Mining News*, 5 August 1909.
- ²⁶ Report for 1896, *Queensland Votes and Proceedings* [hereafter *QV&P*] 1897, vol. 4, p. 18.
- ²⁷ *Croydon Mining Record*, 25 May 1905.
- ²⁸ Herbert Hoover, *Principles of Mining*, McGraw-Hill, New York, 1909, p. 145; C.E. Gregory, *A Concise History of Mining*, New York, 1980, p. 181; Barbara Stack, *Encyclopaedia of Tunnelling, Mining and Drilling Equipment*, 3 vols., Mudén Publishing Co, Hobart, 1995, vol. 3, p.369.
- ²⁹ Foster, *A treatise on ore*, pp. 131, 135, 163; W.H. Tinney, *Gold Mining Machinery*, Crosby, Lockwood and Son, London, 1906, pp. 175, 176.
- ³⁰ Cleland, *West Australian Mining Practice*, pp. 12,13.
- ³¹ Warden's Correspondence, 6 April 1897, 27 April 1897, MWO 14A/G9 and 14A/G10, Queensland State Archives.
- ³² *Queenslander*, 17 November 1888, p. 886.
- ³³ *Queensland Government Mining Journal*, 15 September 1908, p. 489.
- ³⁴ Reported in the *Croydon Mining Record*, 19 August 1910.
- ³⁵ Report of the Under-Secretary for Mines for 1884, *QV&P* 1885, vol. 3, p. 254, and for 1890, *QV&P* 1891, vol. 4, p. 241.
- ³⁶ See example, for Gympie, Report of the Under-Secretary for Mines for 1895, *QV&P* 1896, vol. 4, p. 9, and for 1902, *QPP* 1903, vol. 2, p. 890; for Charters Towers and Ravenswood, Report of the Under-Secretary for Mines for 1901, *QPP* 1902, vol. 3, pp. 253, 255.
- ³⁷ Report of the Under-Secretary for Mines for 1890, *QV&P* 1891, vol. 4, p. 241; for 1891, *QV&P* 1892, vol. 4, pp. 220, 221; for 1892, *QV&P* 1893, vol. 3, p. 561; for 1894, *QV&P* 1895 vol. 3, p. 453.
- ³⁸ Report of the Under-Secretary for Mines for 1903, *QPP* 1904, vol. 2, p. 1150.
- ³⁹ See for example, *Ibid.*, pp. 1150, 1152; Report for 1904, *QPP* 1905, vol. 2, p. 641.
- ⁴⁰ For examples, see Reports of the Under-Secretary for Mines for 1884, *QV&P* 1885, vol. 3, p. 135; for 1900, *QV&P* 1901, vol. 4, pp. 323, 330; for 1904, *QPP* 1905, vol. 2, p. 1016; for 1907, *QPP* 1908, vol. 3, p. 454.
- ⁴¹ *Croydon Mining Record*, 23 January 1903, 13 July 1905.