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Do Australian 19th Century Gold Discoveries have Implications for Interpreting Early Gold Mining Elsewhere?

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Abstract

Eight discovery histories of well-documented Australian goldfields indicate the bonanza recoveries available to "first-movers" into previously unmined areas. These have implications for how we interpret goldfields elsewhere that have been repeatedly re-worked since Antiquity and where earliest exploitation has left no clear record.

Australian gold was first mined after European settlement in the 19th century, and the manual techniques in the initial stages were not substantially better than available to Bronze Age miners. Dry blowing was used extensively in both arid and seasonally dry regions, often as an initial step followed by transport to a water source. The ease of gold recovery from placers conferred a huge competitive advantage over lode gold, which required crushing and grinding. Hence, early production was generally dominated by free gold recovered from proximal settings including non-alluvial placers (residual, eluvial, colluvial, and hillslope areas).

Earliest returns were often prodigious: 5 to 50 grams of gold or more per miner per day in the discovery phase, and 1-5 grams while unworked ground remained. Commonly these high returns were prolonged by "rolling rushes" in which multiple nearby gold occurrences were discovered. Nevertheless, production waned rapidly (within 2-15 years) unless major lodes or large distal placers were discovered. Early returns are not a good predictor of overall productivity: more than 90 percent of gold was recovered in the initial burst of activity on some fields.

Colluvial and proximal alluvial placer mining overwhelmingly dominated early production in most Australian goldfields but leave minimal archaeological evidence. That was probably the case elsewhere in the world, where gold was first mined in the Bronze Age or earlier, and we should heed this when interpreting their earliest mining phases.

Introduction

Earliest gold production throughout most of the Old World was in Antiquity. Records are sparse and generally the archaeological evidence is obscured by successive later mining campaigns. Mining is inherently destructive: hence every mining period, be it Modern, Medieval, Classical or Bronze Age, operates to the detriment of the landscape and to the archaeological footprint of earlier periods. Small-scale placer workings typically leave minimal permanent impact and are easily obliterated by later mining (Timberlake, 2019). Modern open-pit mining is particularly destructive (Weisgerber and Pernicka, 1995), as are unregulated artisanal activities (McLean, 2017). For this reason field evidence for ancient gold mining is often lacking. Paradoxically, traces of early mining that would not otherwise be known can be revealed by later mining, thus offering an opportunity for documentation and partial presentation as was the case in the Iberian Pyrite Belt (Salkield, 1987).

By contrast, Australia's goldfields were discovered in many sites around the continent (Figure 1) in the period 1851-1900. These discoveries were "virgin", rather than being re-discoveries of sites worked in multiple periods far back into prehistory. Generally, they were made in remote areas initially without local infrastructure, but in regions under the authority of centralised governments and bureaucracy (at the state or rather "colony" level since Australia did not become an integrated nation until federation in 1901). This bureaucracy, although often resented by the "diggers" on the goldfields, led to better oversight, inspection and recording than was the case for gold discoveries in most other parts of the world. In

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addition, reliable early documentation exists through discoverer's diaries, contemporary newspapers, and by early visits from government officials, including well-respected geologists. Many of these records are preserved and accessible, thanks in part to the efforts of the various state geological surveys in making digitized copies searchable and freely available.

Australia therefore offers unparalleled insight into early production on new goldfields, and hence Australian discovery case histories should be of interest to a wider community than just local mining historians.

Research methods

This paper is a synthesis of existing documentation, focussing where possible on the earliest surviving official or verifiable accounts, and on those fields for which reliable early production records exist. It is informed by a broader perspective from the author's mineral exploration career spanning more than 40 years, including field exploration in all but one of the districts discussed (Lisle in Tasmania was only visited briefly twice, in 2001 and 2005). Although my focus was discovering new mineral deposits, the location and nature of former mining sites was always compiled and assessed first.

After clarifying terminology and then introducing Australia and its gold endowment, this paper presents eight case histories as exemplars for the nature and production profiles of gold from newly discovered deposits. I then discuss some of the main outcomes and suggest that these considerations might apply to the earliest stages of gold exploitation elsewhere.

Terminology

I refer to all primary gold deposits as "lodes", irrespective of their form (quartz veins, shears, stockworks, etc.). Those in which the sulphides are predominantly unweathered are "sulphide lodes", whereas I use the term "oxidised lodes" when most sulphides are weathered.

I use "placer" to indicate material in which gold has been physically concentrated, owing to its high density, after its release from lodes by weathering processes. Placer gold includes fine particles (gold dust or "flour gold"), micro-nuggets, nuggets, and composite nuggets (gold-bearing material containing other minerals like quartz or ironstone, in which gold makes up a large enough proportion to cause the composite fragment to act as a heavy mineral in its own right - typically this is 10 % by volume gold or more). Placer concentrations occur typically at the base of soil or alluvium but can be at higher levels, especially in arid settings (Wells, 1989).

I use the term "colluvial placers" where gold concentration dominantly involved processes like physical settling during soil creep, differential removal of lighter components through bioturbation, or wind deflation and sheet wash. This category overlaps with the residual, eluvial and hillside placers in other terminologies such as the one by Wells (1989).

I refer to "alluvial placers" where gold concentration is dominantly by water processes in defined stream channels. These can be proximal, in what would be mapped as first-order streams, or distal, when further downstream in larger higher-order channels. Alluvial placers can occur in active stream channels or former channels. The latter can be as "deep leads" below current stream levels, or above them as "bench placers". In all cases, the same rules apply: most gold is either at the base or concentrated at specific horizons.

There is an overlap between the colluvial placers and the most proximal alluvial placers: this is the zone of "ephemeral gullies" (Kang, Guo and Wang, 2021) where poorly channelised water flow is locally and perhaps temporarily concentrated in rills and headwater-eroding gutters on hillslopes, and where much of the gold lodges in bedrock crevices and between boulders. I include these environments with colluvial placers while recognizing that others may regard them as alluvial. The reason for this decision is that placers in this transitional environment can only contain minerals from the lode or from the immediate host rock. By contrast, alluvial placers can contain heavy minerals from any rock type present anywhere in their catchment area.

The term "alluvial gold" would be recognised by almost all geologists as synonymous with my category of alluvial placers. However, for some in archaeology the term alluvial gold means something quite different: namely, the selective recovery and processing of gold-bearing rock fragments caught up in alluvial sediment (for example, the "quartz chunks" of Klemm and Klemm, 2013, p.69, 85, 144; Harrell, 2024). For that reason, I avoid the potentially ambiguous term alluvial gold and refer to the style of mining advocated by Klemm and Klemm as "alluvial clast mining". Certainly, this would have happened whenever gold-bearing clasts were recognized, though perhaps more so in the colluvial environment than within alluvial sediment. This is not further discussed here other than to state, in reading hundreds of papers and records on Australian goldfields, I have yet to encounter a case where it is mentioned as a mainstream mining process or a significant ore source.

Australia and its gold deposits

Australia (Figure 1) including the separate island of Tasmania covers about 7.7 million km^2 but is home to just 26 million people who are mainly clustered in the southeast and around the state capital cities. It is the flattest and most tectonically stable of the continents. With the technical exception of Antarctica, it is also the driest: enough rainfall to support luxuriant vegetation or intensive agriculture falls only in the extreme southeast and southwest, along the east coast and within parts of the far north tropics. The remainder of this "hot, dry, red, barren country" is scrubland, savannah or desert, in which the availability of surface water dictates both human and animal activities, and indeed their very survival.

Australia's aboriginal "first nations" people reached the north coast approximately 65,000 years ago (Clarkson, et al., 2022) and, by about 40,000 years ago had occupied the entire continent, including Tasmania. Naturally, they were concentrated in those areas most conducive to survival: near watercourses, estuaries, and wetlands. However, there is evidence for continuity of occupation throughout the land, with regional differences emerging in discrete areas (Tobler, et al., 2017). Their stone technologies were highly developed and record some of the world's earliest advances (e.g. grinding stones, backed blades, hafted implements; refer Dortch, et al., 2019). However, they made no use of metal or ceramics. There is likewise no firm historical, anthropological, or archaeological evidence that Australian aboriginals ever mined, possessed, used, or attached any value to gold prior to European colonisation, though they certainly would have encountered it given their superb bushcraft and their intimate knowledge of country. The sparse evidence is summarised by Cahir (2012, p.7).

Discovery and exploitation of Australia's prodigious gold resources happened well after European colonization but linked to the exploration and development of the mostly arid continental interior. European (British) settlement commenced in 1788 with the establishment of the convict colony of Port Jackson (Sydney). Initially this struggled to survive, and it was only in 1813 that the rugged ranges west of Sydney were crossed by European explorers, thus opening the path to the hinterland. Later settlements included Brisbane (1824), Perth (1829) and Melbourne (1835, after a failed earlier attempt in 1803). It was from these and other coastal settlements that Europeans moved into the interior, first as explorers then pastoralists and prospectors. Those incursions were to the detriment of, and despite opposition from, the aboriginal occupants with their thousands of years primacy.

Australia is a great place to study gold deposits. There are tens of thousands of known gold occurrences (>23,000 in Western Australia alone; refer Minedex, 2023), thousands of mined-out deposits, hundreds of new ones in exploration or evaluation stages, and 162 currently operating gold projects, many with multiple mines (Hughes, et al., 2022). Orogenic-style deposits (Groves, et al., 2020) are especially well represented by Archean "greenstone-hosted" deposits in the west and Phanerozoic "slatebelt-hosted" ones in the east. Other styles include sub-volcanic breccia pipes and intrusion related "porphyry copper-gold" deposits. By contrast, several important types are rare, including high-sulphidation epithermal, Carlin-style, and Witwatersrand-type palaeo-placers.

In 2022, Australia was the third largest gold producer (314 tonnes) behind China and Russia, accounting for about 9 % of the 3,028 tonnes of global mine production (World Gold Council, 2023). It has the largest known share of economically-demonstrated gold resources in the world (21 %) and its production is projected to rise at an average of 6.8 % per year, reaching 390 tonnes per annum in 2025 (Hughes, et al., 2022). Western Australia dominates all categories: past production, current production, and resources. Total recorded Australian production from 1850-2022 is about 15,300 tonnes of gold, which is over 8 % of the estimated world all-time production of 187,000 tonnes (USGS, 2023).

Case histories of discovery

The eight case histories presented below are selected because they have the most complete information, including reliable early production records. They cover a wide range of geographic/climatic and geological settings (Figure 1). If there is a focus, then it is on orogenic-style, quartz vein gold systems because these seem to be particularly important in generating placer deposits; furthermore, they are a favoured target for lode mining owing to their prominence, predictability, and commonly high ore grades. The order of presentation is broadly in discovery order, which proceeded from the 1850's in the southeast of Australia and then anticlockwise around the north to the southwest in the 1890's.

This paper does not discuss in detail the geology of each area but the following publications give some context for readers who are unfamiliar with Australia. Huston, Blewett and Champion (2012) summarise Australia's geology and tectonic evolution, whereas Phillips (2022) discusses the character and distribution of gold deposits in a world perspective. The online book "Shap-

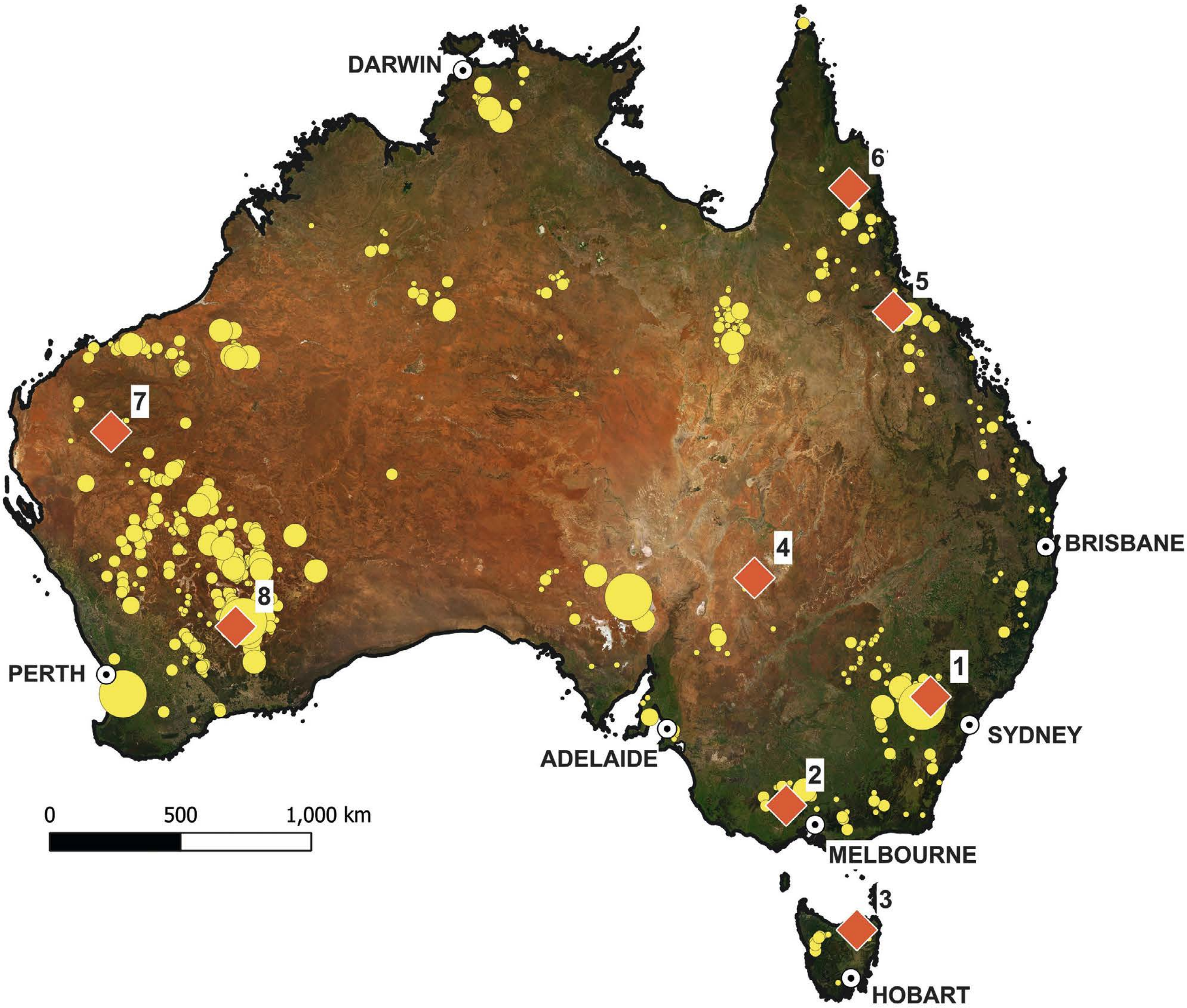

Figure 1. Location of case studies as brown diamonds, showing Australian state and territory capital cities, and current gold resources as graduated yellow circles (Geoscience Australia, 2023). Key for case studies: 1: Bathurst/Ophir, Bathurst gold district (NSW); 2: Ballarat-Bendigo, Victorian Gold province (Vic); 3: Lisle goldfield (Tas); 4: Albert goldfield (NSW); 5: Charters Towers goldfield (Qld); 6: Palmer River goldfield (Qld); 7: Ashburton goldfield (WA); 8: Coolgardie, Eastern Goldfields (WA). NSW: New South Wales; Qld: Queensland; Tas: Tasmania; Vic: Victoria; WA: Western Australia. Background is ESRI World Imagery Satellite: https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}. Projection Lambert conformal conic (EPSG 7845).

ing a nation: the geology of Australia" (Blewett, 2012) provides an overview of Australia, including its natural resources. McQueen (2021) summarises contemporary geological thought and conditions in the Australian colonies while Lock (1882) provides detailed information of many of the early-found mines in the east of the continent. However, Lock's book was written before the major Western Australian discoveries, which dominated within 20 years (Figure 2).

Bathurst/Ophir, Bathurst Mining District, New South Wales (No. 1 on Figure 1)

The first commercial gold discovery in Australia was made by William Tom and John Lister in April 1851, about 200 km northwest of Sydney at the junction of Lewis Pond Creek and Summerhill Creek. Edward Hargreaves is generally credited although, as explained by McQueen (2021), his role was more as an "orchestrator" intent on claiming a discoverer's reward from the Government. In fact, there had been a sporadic history of gold reports extending back to the 1830's, including some that might have been suppressed by officials to prevent unrest among the convict labourers. Unlike some of the following case histories, this area was already well settled because it lies in one of Australia's prime agricultural and grazing regions, the Central Tablelands. Rainfall here is seasonal and variable across the area but typically 600-1,000 millimetres per year (hereafter mm/yr.) depending on altitude.

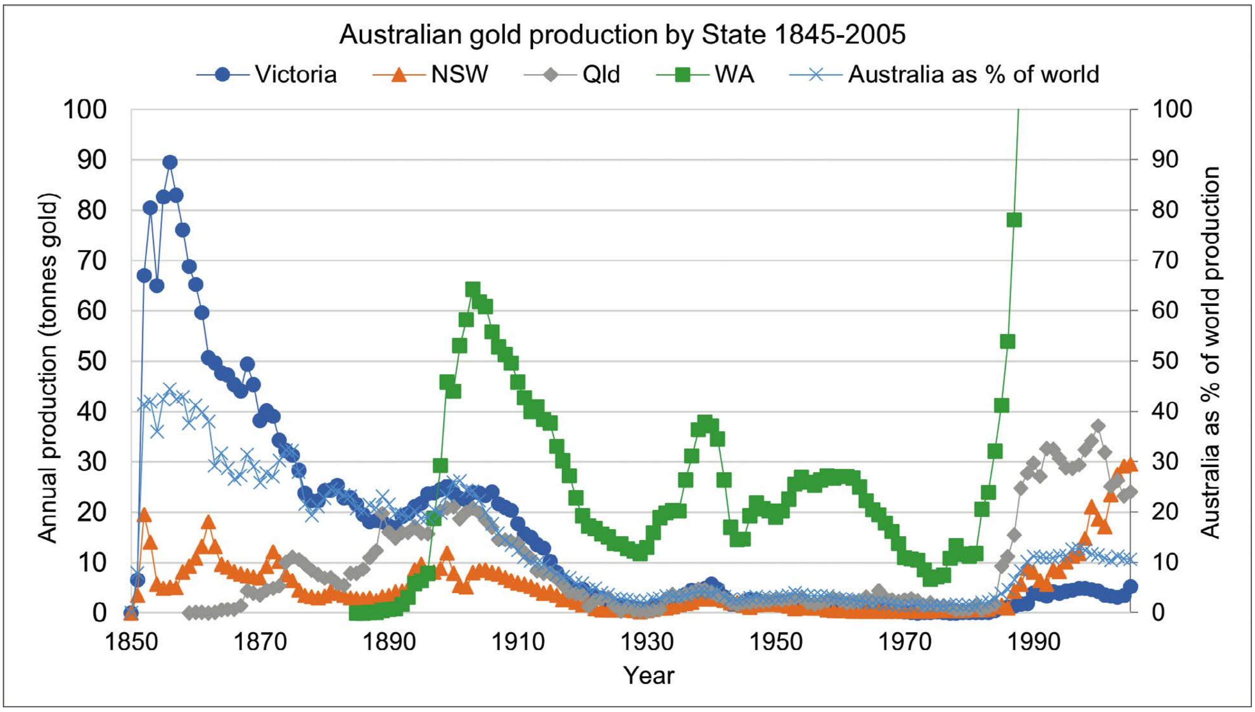

Figure 2. Australian gold production by state 1850-2005 (showing only the 4 most productive states) and Australia's proportion of world annual production. Australian data compiled by the author from various reports sourced from GA (Geoscience Australia) and ABARE (Australian Bureau of Agriculture and Resource Economics). NSW: New South Wales; Qld: Queensland; WA: Western Australia. World data 1850-1899 from Vilar (1991, App.2) and USGS (United States Geological Survey, 2024).

Within six weeks there were more than 1,000 people on the goldfield, which was renamed Ophir by Hargreaves. Numerous additional finds were made over the next few months in the adjoining river systems covering a total area of some 13,000 km^2 (Earp, 1852, p.134; Brownrigg, 1851). By mid-August 1851 there had been 165 kg (5,800 oz.) of gold declared through Customs and an estimated total production of some 260 kg (8,300 oz.: Earp, 1852, p.134, obtained by reference to merchants' accounts). By 18 November, about six months from initial discovery, about 2.1 tonnes of predominantly placer gold had been shipped out (Earp, 1852, p.136); thereafter it is not possible to say how much of the output was placer gold, though certainly it became proportionally less over time. McQueen (2013) concludes that overall production from alluvial placer sources in the district would have been well above the "official" estimate of 18.5 tonnes, with most mined in the first six years to 1856.

Output waned rapidly after exhaustion of the best placers, as evidenced by the total output for the state of New South Wales (NSW) on Figure 2. Later peaks in this state's production correspond to further placer gold discoveries, in 1860 at Forbes (located 150 km west of Bathurst) and at Lambing Flats (150 km southwest of Bathurst- later renamed Young). Forbes produced over 7.3 tonnes of gold in just 12 months from alluvial placers including deep leads (Pittman, 1901, p.10). Both fields had peak mining populations over 20,000 but only for several years.

The Bathurst region has developed in recent years into one of Australia's most important goldfields. This is due mainly to the discovery of the "bulk-mineable" Cadia copper-gold system, which is currently one of the largest producers in the country.

Victorian Gold Province Australia, Vic

(No. 2 on Figure 1)

The Victorian Gold Province lies 100-200 km inland from the state capital Melbourne. It was discovered initially at Castlemaine in July 1851, followed by Ballarat in August, Creswick in September, Bendigo in October, Daylesford in 1852, Stawell in 1853, then other districts over the next 5 years throughout an area of 24,000 km^2 (Hughes and Phillips, 2001). Several of the most important districts (notably Bendigo, Castlemaine, and Creswick) were dominated by placer gold throughout their productive life, though in several this included extensive "palaeoplacers", preserved as deep leads in old river systems that partly extended beneath young basalt flows.

The district has a temperate to cool Mediterranean climate, with no marked dry period, and an annual average rainfall of 500- 685 mm/yr. depending on location. Most is rolling low hills with fertile valleys partly floored by basalt flows. Large gold nuggets are more prominent in this field than any other: the largest recorded was 71 kg, with another 50 exceeding 15 kg (Hughes, Phillips and Carey, 2004). Many of the lode deposits are also characterised by coarse gold so it is probable the nuggets are primary, a finding consistent with the occurrence of large gold-quartz "slugs" in the placers and with modern theories on the hypogene origin of most gold nuggets (Butt, Hough and Verall, 2020; Chapman, et al., 2022).

The Victorian Gold Province is one of the best examples of a "rolling rush" in which multiple districts all contributed their peak production over a short period. In the first decade after discovery almost all the gold was produced from placer workings. Overall production rose within two years up to 70-80 tonnes, representing more than 40 % of world gold production at the time (Figure 2); it peaked around 90 tonnes in 1856, then declined steadily over the next 20 years, before some large sulphide lode mines stabilised production. Mechanical dredges operated in the main river flats around 1935-1955.

Total production from the Victorian Gold Province amounts to about 2,500 tonnes of gold or over 1 % of the world's total cumulative gold (stated to be 2 % by Hughes, Phillips and Carey, 2004; however, ensuing production over the last 20 years elsewhere has lowered that proportion). Several important sulphide lode mines include Bendigo and, more recently, Stawell and Fosterville. Despite these, however, placers including deep leads have yielded more than 55 % of the total production from this remarkable and world-class gold province (Hughes, Phillips and Carey, 2004).

Lisle Valley, northeast Tasmania

(No. 3 on Figure 1)

Lisle is in the northeastern part of the island of Tasmania some 35 km from the coast. It lies in a bowl-shaped, upland valley about 4 km across, with total area less than 20 km^2 and up to 400 m elevation difference from valley floor to confining ridges. Two streams coalesce and then drain out through a narrow rocky gorge to the northeast. No payable gold has been located downstream of this gorge and there is no evidence for an older sedimentary unit that might indicate transport into the valley from a distant source. Slate and sandstone dominate the surrounding hills, but the valley is floored by an intrusive granite (Twelvetrees, 1909, Plate 3). The district has a temperate maritime climate with a winter rainfall maximum (average 655 mm/yr.), leading to abundant water flow in permanent streams.

Gold was discovered by the Bessel brothers in late 1878, following earlier discoveries in the previous year some 10 and 20 km to the to the north (Preston, 2014, Fig.1). A small rush ensued in the following January initially involving about 100 miners. Contemporary newspapers reported that miners were earning "£3-4 a week" (Coroneous, 1995), which would equate to better than 4 grams of gold per day; no doubt this contributed to the rapid influx of miners, and the rate was not sustained. The population peaked by year-end at around 2,300 (Coroneous, 1995) but had dropped to 350 by late 1881.

Gold in the Lisle valley is confined to the valley floor and hillslopes, in shallow "wash-zones" in the active stream channels, and as "bank deposits", the latter presumably representing incised former channels. Some areas were extraordinarily rich (better than 1 oz. per "cartload", or about 30 grams per tonne) but all parts of the main creeks and banks were productive. Some zones had strong basal gold concentrations over what was described as "soft granite bedrock", but in others the gold was distributed throughout the alluvium and colluvium. The deepest zone mined was only 4-5 metres.

"Pot-hole mining" and creek diversions followed by sluicing dominated the early activities on claims worked individually or by small groups. The field produced at about 12.5 kg (400 oz.) per week for 3-4 years (Twelvetrees, 1909, p.21), with an officially reported total production of 2.6 tonnes (84,000 oz.) up to 1909 but estimated at 7.8 tonnes (250,000 oz.) by Twelvetrees and others (with much of the gold repatriated to nearby Victoria by returning diggers). Production after 1909 was negligible: no additional satellite fields were located, and no mineable lodes were discovered. Hydraulic sluicing and dredging were attempted in later years, but yields were poor and uneconomic (Coroneos, 1995).

The origin of the gold at Lisle is uncertain, even today. Some have speculated that the bowl-shaped valley was originally a mountain lake; however, its infill is consistently described as coarse, locally-derived clastic sediments (Marshall, 1969, App.1 and 3). After his visits to Lisle, the experienced British geologist William Harper Twelvetrees (1909, p.29) concluded: "*Whence all the gold has been derived which has been won in the form of alluvial has long been a mystifying puzzle, baffling the prospector and the visiting expert alike. A quarter of a million ounces have been obtained from a mere fractional portion of an area not exceeding a mile and a half square. The bulk of this has been sluiced from the bed and banks of the Main Creek and from terraces sloping down to it on the eastern side of the valley; the remainder has been won from small creeks on the opposite side of the basin and from terraces above them. The remarkable feature of the* *field is that no reefs have been found either in the valley itself or on the surrounding hills. Certainly some quartz veins must exist concealed beneath the mantle of overburden which clothes the hill-sides, because numerous stones of quartz occur in the drift; but this quartz is barren. […] The auriferous overburden which covers the bedrock has not been brought by torrents from afar. The gold has not travelled. The terraces consist of hill detritus-not of shingly beds. Apart from the bottom wash of the terraces, the only shingle in the valley is that of the creeks or of their ancient beds. The creeks themselves are contained within the valley walls. With these conditions one cannot escape from the conclusion that if the gold has been shed from quartz reefs specimens of auriferous quartz will be found in the workings. But such quartz is absent, …".*

No advance has been made on Twelvetrees' conclusions over the succeeding 120 years.

Albert Goldfields, northwest New South Wales

(No. 4 on Figure 1)

Numerous small gold discoveries were made in 1881-82 over an area of about 900 km^2 in northwestern NSW. The area is remote, arid (average rainfall 242 mm/yr.), sparsely vegetated, and with almost no water apart from rare storms and flash flooding. All information here is extracted from the excellent summaries by McQueen (2007; 2008), together with field visits by the author in 1994 and 2004.

Early production was largely from colluvial (residual-eluvial) and shallow "gulley" placers; most gold was recovered by dry blowing or by carting the sieved "washzone" material to the scarce water sources. "Puddling" (agitation and disaggregation under water, using horsepower) was necessary to prepare some of the material before sluicing. The gold was generally coarse and "shotty", with some large nuggets.

As was commonly the case in Australian goldfields, this field was subject to "rolling rushes" when the small placer occurrences were quickly exhausted, and new ones discovered nearby. Around 2000 people were involved at its peak, distributed in 4 small townsites and about 20 "shanty settlements" at the working areas. Some early reports described grades as high as "3 ounces to the load" (a cartload of about 1 tonne weight, hence in the vicinity of 100 grams per tonne and thus extremely high grades for placer gold). However, returns were not spread equally, and many "diggers" struggled to find enough gold to survive in this bleak and remote environment, with prohibitive prices for both food and water.

Highest annual production of about 370 kg (12,000 oz.) was recorded in the first year after discovery and no subsequent year exceeded 155 kg (5,000 oz.; McQueen, 2007, Fig.7). The rich, but shallow and small, near-surface placers were effectively exhausted within two years, after which attention focussed on the search for alluvial "deep leads" and on evaluating the small but numerous primary lodes (quartz veins) that had been discovered. Despite some good results from early crushing, the lodes were not economic, and the rare deeper alluvial placers were poor and discontinuous. The goldfield was effectively finished as an economic proposition within ten years after its discovery although metal detecting activity continues today. Total recorded production was just under 2 tonnes of gold up to 1945, almost all from colluvial and proximal alluvial placers; lode production of only 45 kg was less than 3 % of the total (McQueen, 2008).

This was an enigmatic and confusing goldfield in that the near-surface gold did not match the distribution of known quartz lodes. McQueen (2007; 2008) speculated that the gold had been recycled through Mesozoic sedimentary cover sequences which then had been stripped off again, leaving the gold as a residual placer on the former unconformity surface but still close to its original primary sources.

Charters Towers, northern Queensland

(No. 5 on Figure 1)

Charters Towers lies about 1,000 km northwest of the Queensland state capital, Brisbane, and 100 km inland. It differs from the other cases presented here because it had virtually no placer mining; hence lode gold production dominated from the outset. The area has subdued relief but contains rocky outcrops and well-developed, seasonally-active drainages. Its climate is sub-tropical, with a hot and humid summer but a dry and warm winter. Average rainfall is 660 mm/yr., but variable, depending on cyclone frequency.

The discovery was made in December 1871, probably by an aboriginal boy "Jupiter" in a prospecting party led by either George Sharp or Hugh Mosman (Menghetti, 1984 p.9; Marsland, 1892, p.7). It was one of many significant goldfields discovered in close succession in Queensland, including Gympie in 1867, Ravenswood in 1868, Etheridge in 1871, and Palmer River in 1872 (the last discussed further below). A rush ensued in the early months of 1872, with many participants being experienced miners from Victoria, NSW, or other Queensland goldfields. However, their activities were initially restricted because they arrived in the dry season and hence there was insufficient water to process the crushed rock. Multiple gold-bearing quartz lodes were exposed in the streams and on hillslopes, but placer gold was so scarce that it did not rate a mention in early reports. Marsland (1892, p.7) remarked: *"Although alluvial gold was worked in a deep lead near Millchester for a short time, it may be stated generally that the Charters Towers gold field is to all intents and purposes solely a reefing field …"*.

The goldfield was proclaimed originally over 4,400 km^2 but later reduced to 1,550 km^2 (Menghetti, 1984, p.11). However, almost all recorded production came from an area of less than 10 km^2 around and under the subsequent townsite. The ores are unusual in that they consist of base metal sulphide-rich, gold-silver-quartz lodes, of "mesothermal" type, hosted in granite (Kreuzer, 2005).

The oxidized near-surface zones of the quartz reefs dominated early gold production; these were well-exposed, large and with consistently good grade (though the contained gold was dominantly fine grained). However, mining them was difficult in the early years owing to the scarcity of water at the surface (but its over-abundance within the workings), the lack of crushing facilities, and the numerous small claims worked by individual miners. From about 1875, large companies began to consolidate the claims, after which the field advanced by deep mining supported by steam-driven pumps and mechanical crushing. That phase continued with increasing production (Figure 3) for more than 25 years owing to sustained grade and continuity of the lodes at depth.

Total production to 1972 was 206 tonnes of gold at a very high average grade of over 34 g/t, making Charters Towers the richest large goldfield in Australian history. Unlike many of its neighbouring gold districts, it did not experience a revival in the subsequent mining booms of the 1980's or more recently. There are, however, substantial gold resources at depth which have been periodically assessed for development.

The reason for the scarcity of placer gold at Charters Towers is not well understood and the contrast is stark with the Palmer field, discussed next: both are in similar tectonic, topographic and climatic settings, and both have primary gold in numerous quartz lodes.

Palmer River, northern Queensland

(No. 6 on Figure 1)

This field is situated 1,300 km northwest of Brisbane and 100 km from the east coast across a rugged divide (the northern extension of the Australian Great Dividing Range). The seasonally-active Palmer River flows west from the divide to join the Mitchell River, before flowing eventually into the Gulf of Carpentaria. The goldfield lies in steeply incised ranges in a tropical savannah setting, with high but seasonal rainfall (1,000 mm/yr.) coming mainly from summer tropical storms and cyclones. Flooding is interspersed with dry periods in which streams are reduced to interconnected pools with limited flow; this strongly influenced mining activity.

The initial discovery was made in 1872 by the explorer William Hann and an accompanying geologist Norman Taylor; they named the Palmer River and reported traces of alluvial gold. In June 1873, a prospecting party led by James Venture Mulligan set out to follow up these reports across trackless country 260 km north from the nearest settlement at Georgetown. Since Mulligan's party was the first to prove "payable" gold, he is often credited as the discoverer. Reliable information about his expeditions and the early years of the field comes from his published journal (Mulligan, 1875), backed up by contemporaneous newspaper accounts and reports from mining wardens and government geologists who inspected the workings in early years.

In their first expedition, Mulligan's party of six returned after three months (including travel) on 3 September 1873 with about 3.2 kg (102 oz.) of gold (Kirkman, 1984, p.10), representing an average yield of about 7 grams of gold per man per day (the need to guard camps against attacks from aboriginals, plus the large travel time, meant that recovery per productive mining day was much higher, perhaps three or four times that). The remote and harsh country offered severe challenges such that marginal production would not be sufficient to justify travel and effort. As the expedition leader remarked (Mulligan, 1875, p.12): *"We may prospect for gold, but when on it will not work for less than 1 oz. per man per day; less will not pay us for our expense and loss of time; and though a day's work may result in four or five times that, yet it must be considered exceptional."*

A "rush" ensued after news of the discovery, resulting in numerous additional finds throughout the district. According to Lam, et al. (1991, p.17), the first arrivals recovered an average 70 g of gold per day, while Kirkman (1984, p.24) reported this as 45 g. The newly appointed mining warden, Howard St George, estimated an average per miner over the first month of "£1 per day" (Kirkman, 1984, p.41), which equates to about 7.5 g. All these estimates have a high uncertainty owing to the poor early population records. However, by 1887 output per miner had dropped to "20 oz. 17 dwts per year"[1] (Queensland Department of Mines, 1878, p.8), which is about 2.6 g per miner per day at 300 working days per year. This was barely equivalent to a labourer's wage of £2 per week (Mengheti, 1982, p.70), or 2.5 g gold per day at the prevailing gold price for Palmer gold of £4 3s (Mengheti, 1982, p.94).

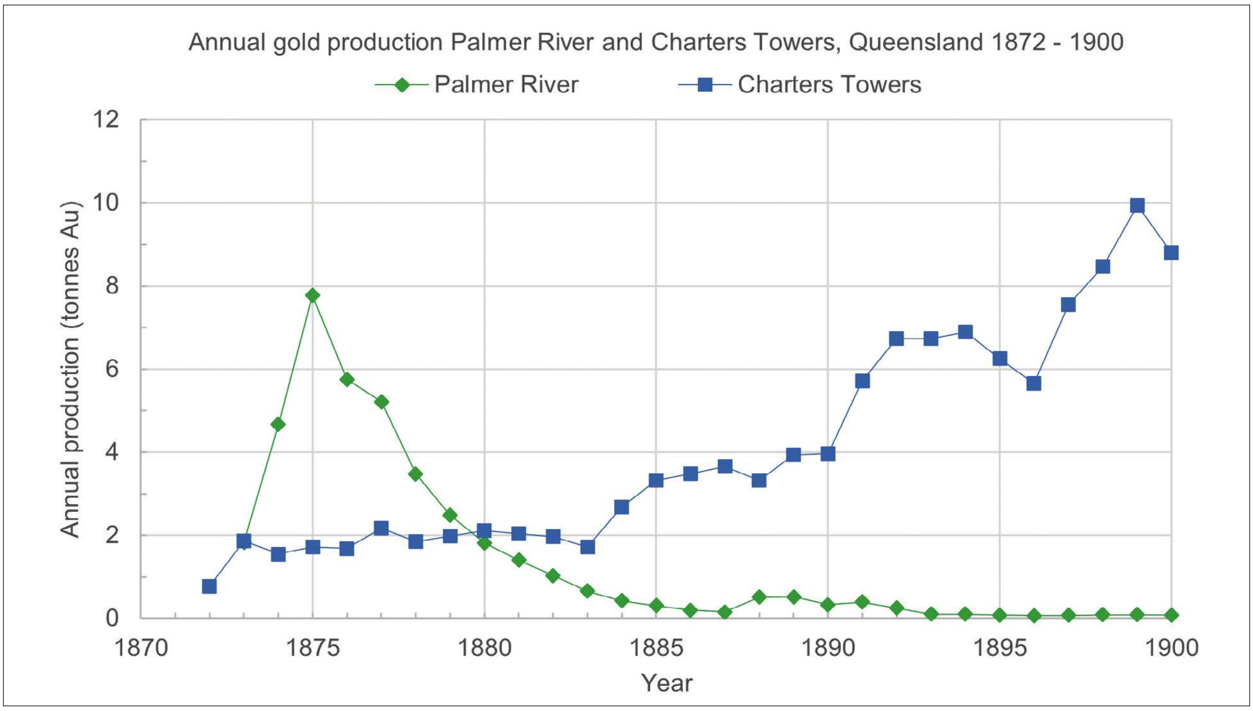

Figure 3. Gold production (tonnes per year) 1872-1900 for Palmer River and Charters Towers goldfields, Queensland. Palmer River data from Jack (1888) and, for the waning period 1888-1900, from Kirkman (1980, Tab. 3, p.144). Charters Towers data from Menghetti (1984, p.54) reproduced from Levingston (1974).

As with other gold districts, there were numerous "rolling-rushes" when new areas were discovered, and the earliest-found areas became depleted. Peak annual output (Jack, 1888, p.15) was in 1875, just two years after Mulligan's confirmation of Hann's discovery, at just under 8 tonnes (250,000 ounces) of gold; however, this declined steadily thereafter (Figure 3). The highest population on the field probably reached about 20,000 in 1877 (Kirkman, 1984, p.55), being dominated by Chinese. The European mining population peaked at 3,000 in 1876, then declined sharply. Even most of the Chinese left soon after owing to exhaustion of the best placer ground, together with the lure of newly discovered goldfields elsewhere. By the end of 1883 the total population had slumped to 842.

Most of the gold came from an area of 2,500 km^2 extending over the eastern (upstream) part of the catchment of the Palmer and its numerous tributaries, with some occurrences lying outside the watershed, to the south and southeast. It was won from shallow colluvium on steep hillsides, "gully placers", active fluvial channels and gravel bars, together with some "perched gravels". Features evident today are the shallow depth of stony colluvium over most of the rocky hillsides and the limited quantity of alluvium in many of the first-order streams. It is difficult to determine if these were always the case or resulted from the intensive mining; however, Jack (1888) noted the same and speculated that the gold might have been sourced from unconformably overlying Mesosoic sediments that had been subsequently eroded, leaving a residual gold enrichment. This has not been borne out by later geological studies and a more obvious source is the literally thousands of "orogenic-style" quartz lodes in many swarms throughout the field. Most of these have been prospected, pitted, and trenched, generally without yielding payable gold. Only about 15 quartz lodes have any recorded production.

Lam, et al. (1991, p.12) estimated "official" production for the Palmer River goldfield of 41.5 tonnes (over 1.33 million ounces), with 90 % from placer sources. However, they noted that total production might have been much higher, with a substantial but undocumented amount taken back to China by returning miners (Bolton, 1970, p.58). For the early years, which dominated production (Figure 3), the most reliable figures are given by Robert Logan Jack, a government-appointed and experienced Scottish-trained geologist; the credibility of his figures is enhanced because these are tabulated in a contemporary account, in a government-sanctioned publication and backed by multiple site visits. Jack (1888, p.14) gives total gold production up to the end of 1887 of 39.6 tonnes (1.272 million oz.), comprising 37.2 tonnes (1.197 million oz.) of placer gold compared with only 2.4 tonnes from lodes.

The predominance of placer gold in such a large production total, but with no major "deep leads" is striking. As Jack (1888, p.14) categorically stated: *"Ninety-four per cent, of the gold hitherto obtained from the Palmer has been alluvial gold."*

The isolation and lack of infrastructure certainly contributed to difficulties in developing this goldfield, and numerous attempts have been made in the ensuing 130 years to re-start both placer and lode mining. However, none has yielded significant returns, and most have been disastrous failures. After summarising these, Kirkman (1980, p.142) remarked: *"Best remembered as a gloriously rich poor man's field in its early alluvial years, the Palmer has been romanticised by writers […]. But for most of its time, it was a socially debilitating region, and a hellish sink for misdirected and hard-won capital in its reefing phase."*

A visit to the Palmer today, some 150 years after its heyday, reveals limited evidence for the placer mining although it is likely that virtually every creek and gully was turned over multiple times. There are some remnants of retaining dams breached by floods, a few infilled trenches that might have been diversions or sluicing runs, and some lines of stacked boulders that might have been moved out of the channel to uncover a basal gold-bearing wash. By contrast, although they produced hardly any of the gold, many of the quartz lodes retain the evidence for trenches, pits, and shafts sunk in expectation of finding the "motherlode", which never happened in this field.

Ashburton, northwest Western Australia

(No. 7 on Figure 1)

The Ashburton goldfield lies nearly 1,000 km north of Perth, the capital of Western Australia, and over 300 km inland along the occasionally flowing Ashburton River. The initial discovery in January 1890 was made at Top Camp and then, over the next few months, at several widely scattered locations within an area of about 1,500 km^2. This is a remote and inaccessible region with severe water-availability issues in the hot and dry summer months; hence it never attracted more than a few hundred hopeful miners. Average rainfall is just 275 mm/yr. The streams are totally dry for most of the year, though subject to flash flooding during sporadic intense cyclones.

Most of the gold was recovered from proximal alluvial and colluvial placers, particularly from hillslopes, steep gullies, rock crevices, and in between "slate boulders" in the ravine-like stream beds. More than 70 % of all production was from the original discovery site Top Camp and in its adjoining steep gullies and ridge slopes, over an area of about 2 km^2.

Reliable early information was provided by Henry Page Woodward, a British-trained geologist who was appointed the Chief Geologist of the Western Australian Mines Department in 1887. After a visit in June 1890, just 6 months after the initial discovery, he remarked (Woodward, 1891, p.22): *"This field, as far as it has been worked, has produced the most gold in the shortest time of any field in the Colony, for about 15,000 ounces have been raised in about six months."*

This equates to about 465 kg, with two thirds of that, nearly 300 kg, recovered from Top Camp.

Woodward commented further that: *"All these gullies will pay to work again and again after such heavy shower of rain, as their beds are so small and deep that they will act as ground sluices, re-sorting all the dirt which has been imperfectly treated by the process of dry blowing."*

However, the promising start of this goldfield was not fulfilled. The following decades saw literally thousands of gold discoveries in the colony of Western Australia, especially in the Murchison (Mt Magnet, Cue-Day Dawn, Meekatharra, and others) and in the Yilgarn/Eastern Goldfields (Southern Cross, Coolgardie, Kalgoorlie, Norseman, Wiluna, Kanowna, Mt Morgans, Sons of Gwalia, etc.) but nothing significant in the Ashburton district. Although several small mines were later developed in the general region during the 1980's, there are still no significant deposits known within the area encompassed by the original discoveries. From this zone over the ensuing 130 years, no more than a few hundred additional kg of gold have been recovered by dry blowing and, more recently, by use of metal detectors. Based on the compilation of later production by Thorne and Seymour (1991, p.115), the first six months might have produced more than 50 % of the gold ever recovered from the original Ashburton goldfield.

Coolgardie, Eastern Goldfields Province, Western Australia

(No. 8 on Figure 1)

The discovery site "Bayleys Reward" lies about 500 km east of Perth, and about 2 km northeast of what is now the townsite of Coolgardie. It has a subdued topography with poorly developed drainage (mostly by sheetwash in broad depressions, with discontinuous incised channels) and small cliffs locally called "breakaways". This is a semi-arid region with very dry summers and low rainfall (248 mm/yr.), mainly arriving in a short winter period. The characteristic ferruginous laterite capping of this deeply weathered region had either not developed or been eroded to leave a veneer of stony colluvial detritus, overlying deeply weathered and disaggregated

Figure 4. Photograph taken probably in 1894 looking west-southwest across Fly Flat towards Coolgardie. Note shallow excavations in foreground and dry blowing or shaking table within the group of men. The road to the newly discovered Kalgoorlie goldfield passes out between the buildings and to the left (with two horse-drawn wagons setting out). The caption is incorrect: Mt Eva lies some 500 m north (to the right) of the vantage point. Used with permission of the Coolgardie Goldfields Exhibition Museum.

greenstone saprolite (the weathered surface equivalent of the metavolcanic rock that hosts the lodes at depth).

Two prospectors, Arthur Bayley and William Ford, made the discovery in 1892 (in mid- August according to Blatchford, 1898, p.12, but other reports claim it was in June) after travelling overland on horseback through desolate scrub for 200 kilometres east from Southern Cross, the closest population centre (itself a gold discovery made a few years previously). They found over 6 kg (200 oz.) of gold nuggets on the surface of a plain they called "Fly Flat" and then later even more gold in a "quartz blow" (rubble from a quartz vein) just to the east. Bayley returned to Southern Cross on 17 September 1982 with over 17 kg (554 oz.) of gold, precipitating a rush to the area (Ford stayed to guard the find against claim jumpers). Within two months, about 150 men on the field had recovered 93 kg (3,000 oz.) from the "alluvial" workings (Blatchford, 1899, p.12). The discoverers' "reward claim" alone (an area of 5 acres or about 20,000 m^2; refer Calvert, 1894, p.105) then yielded 140 kg (4,500 oz.) of gold in 12 months to June 1893, whereupon it was sold (the two finders retaining a minority holding). The new owners then recovered another 280 kg (9,000 oz.) from it within six months, with the maximum excavation up to that time being only "8 feet deep" (Calvert, 1893, p.40). Subsequently the original claim and surrounding leases were combined and floated as a public company. Under various names this went on to become a significant underground mine which operated until 1963 (though mines on adjoining leases are still operating today).

This district is characterized by supergene enrichment of gold deposits, but typically that is developed at depths of 40-50 metres while the near-surface zones are depleted of most gold. It is likely, therefore, that the initial discoveries had benefitted from long periods of differential physical concentration through selective removal of light materials which, after being brought to the surface by bioturbation, were subjected to wind deflation and sheet-flooding. The near-surface gold occurred as fine particles, nuggets, and composite quartz-ironstone-gold aggregates.

Photographs taken in the early days of mining at Coolgardie are shown in Figures 4 to 7. Like most goldfields in arid Australia, dry blowing was used extensively to recover the gold. The newly appointed Government geologist Torrington Blatchford gave detailed descriptions of the various dry blowing procedures (Blatchford, 1899, p.54). He noted the process was highly inefficient and that spoil piles after dry blowing still averaged "*at least 10 dwts per ton*"[2]. After producing the first geological map of the area, he stated (Blatchford, 1898, p.60): "*The form in which the gold has been thus found is variable, changing from coarse nuggets and slugs to so fine a quality that up to the present all efforts of the dry-blowers to recover it have been useless.*"

The entire vicinity of the discovery claim is now, of course, strongly disturbed by 130 years of semi-continuous mining activity and partly concealed under waste dumps. It lies close to a low drainage divide between north-westerly trending sheetwash and south-easterly

Figure 5. Dry blowing at Coolgardie using two gold pans. A breeze blowing from the back to the front deflects light material to miss the bottom dish, whereas dense particles including gold fall vertically into it. Note the shaker and screen in the background to remove largest fragments and achieve first-pass concentration before dry blowing by pans. Used with permission from the State Library of Western Australia (Call No: 3542B/350).

trending active (but ephemeral) drainages leading towards a salt lake (a flat, generally dry internal drainage sink that is salt-encrusted). The immediate area contains small outcrops of greenstone saprolite interspersed with soil and colluvium varying from 0 to 8 metres in depth. The early-mined material appears to have been mostly red loam and colluvium containing abundant angular rock fragments including vein quartz, with no significant contribution from water-borne transport other than surficial sheetwash (observations by the author during a site inspection and examination of drill cuttings in July 2003). It is best considered as a colluvial placer (or a residual/eluvial placer in the terminology of Wells, 1989) developed above and around deeply weathered and disaggregated quartz-rich lodes.

The early-won gold at Coolgardie is described in most early accounts as "alluvial", but this was a function of mining law: alluvial gold was defined as "any loose soil earth or other substance containing or supposed to contain gold not being a seam, lode or quartz vein". This was subject to different regulation than lode gold deposits, which caused chaos in such a deeply weathered area, where proving the existence of a lode might require 3-8 metres of excavation. Elsewhere in the wider Coolgardie district, however, gold occurs in true alluvial placers, within ancient river channels of Tertiary age called "deep leads" or "inset valleys" (De Broeckert and Sandiford, 2005, especially their Fig.3; Smyth and Barrett, 1994). Many of these "palaeochannel gold" deposits have been mined in the Eastern Goldfields with some yielding high-grade ores (30-50 g/t). Both physically transported placer gold and chemically precipitated gold contribute (the latter relating to the unusually high groundwater salinities; refer Smyth and Barrett, 1994; Anand, et al., 2019).

Like many Australian goldfields, Coolgardie and the later discoveries in the Eastern Goldfields region experienced severe water difficulties. In this case, however, the issues were mainly of quality not quantity. Groundwater was available in places by digging a well or drilling

Figure 6. Miner dry blowing with screen and shaker. Location unstated, but within the Eastern Goldfields and possibly near Coolgardie. Sieved dry soil or sand is placed into the back, then a rocking motion causes it to pass forward and downward on a sloping platform with lodgement of the heaviest particles behind the cross-wise riffles. The operator would pause periodically to empty out the gold-bearing material from behind the riffles. Any large nuggets are picked off the screen. Sophisticated models also incorporated foot-operated bellows to blow out the light particles and fluidise the soil. Used with permission from the State Library of Western Australia (Call No: 010178PD).

Figure 7. Photograph entitled “Panning off, Fly Flat, Coolgardie” and dated to 1891 in the catalogue in which it is preserved. However, that date must be in error because the Coolgardie discovery was in mid-1892, and the photo shows an overhead telegraph line to Kalgoorlie, which opened in September 1893. The view is towards the northeast, possibly with Bayleys Find in the distant trees (Coolgardie township is directly behind the photographer; refer Figure 4). Presumably the photograph was taken after heavy rain because surface water is also present in depressions in the background. Note that the excavation is in stony colluvium and possibly sub-outcrop. It is also possible that the material being panned had been pre-concentrated by dry blowing as in Figures 5 and 6, then stockpiled awaiting rain. Used with permission from the State Library of Western Australia (Call No: 090711PD).

a bore, but it was inevitably saline or hypersaline (some with up to 10 times the NaCl-equivalent of seawater), thus requiring expensive wood-fired desalination to be useful. This issue was not solved until the opening in 1903 of a nearly 600 km long pipeline bringing fresh water from the hills near Perth. That infrastructure is still in use today and critical to the goldfield communities.

Coolgardie rapidly transitioned to a major lode mining goldfield in which first shallow oxidised and later deep sulphide ores dwarfed the early production from “alluvial” gold. However, of even greater significance is that it resulted in a major goldrush that in turn precipitated discovery of hundreds of additional gold districts containing thousands of tonnes of gold. These included the world-famous Kalgoorlie “Golden Mile”, located 40 km to the northeast and discovered by a party travelling out from Coolgardie in June 1893. Those mines alone have produced over 1,800 tonnes of gold in the 130 years since discovery (Northern Star, 2023).

Synthesis

What can we make of these disparate Australian discovery histories that might informs us about goldfields elsewhere? First, that the rewards can be prodigious for the “first-movers” (and their “fast-followers”) into virgin gold areas: they had access to gold progressively accumulated over the preceding millennia (in some cases perhaps benefitting from weathering processes extending back for millions of years). Certainly 5-50 grams of gold or more per miner per day was achieved in the early discovery phases of most fields. However, rapidly increased mining populations soon reduced this to 1-5 g while un-

Table 1. Productivity estimates for case history Australian goldfields during their evolution.

Region and state	Description and date	Duration (months)	Production (kg) [1]	Population of field	Productivity (grams gold per person per day) [2]
Bathurst/Ophir (NSW)	First 6 months after discovery (to November 1851)	6	2,100	10,000 [3]	1.4
Victorian Gold Province (Vic)	Highest yearly production (1856)	12	90,000	175,000 [4]	1.7
Lisle Valley, (Tasmania)	Average monthly production over first 3-4 years (1880-83)	1	50	2,300 [5]	0.9
Albert goldfields (NSW)	Peak production in first year after discovery (1881)	12	370	2,000 [5]	0.6
Charters Towers (Qld)	Typical year of first 10 years (1881)	12	2,034	20,000 [6]	0.3
Palmer River (Qld)	Discovery expedition, including travel (mid-1873)	3	3.2	6	7.1
Palmer River (Qld)	Highest yearly production (1875)	12	8,000	10,500 [7]	2.5
Palmer River (Qld)	Peak population but declining production (1877)	12	5,218	20,000 [7]	0.9 [8] / 1.3 [9]
Palmer River (Qld)	Declining population and production (1881)	12	1,405	5,600 [7]	0.8
Ashburton River (WA)	First 6 months and peak production (Jan – June 1890)	6	465	300 [10]	10.3
Coolgardie (WA)	Discovery expedition including travel (mid- 1892)	3	17	2	113.3
Coolgardie (WA)	First 2 months after proclamation (late-1982)	2	93	150	12.4

1: Refer relevant text section for sources of production estimates and population if not indicated otherwise by notes. 2: Daily productivity, based on weeks of 6 days, hence 25-day months, 300-day years, and on full population at the goldfields (so including non-mining support personnel such as merchants, hoteliers, teamsters, troopers, administrators etc.; also including women and children, though these rarely were present in number). 3: Estimate based on a known total of 1,000 after six weeks and increasing at > 2000 per month to 30,000 by year end. 4: Estimate based on census population of Victoria of 348,500 (Government of Victoria, 1858) and assuming half were on the goldfields (40 % were there four years later in 1860; refer Government of Victoria, 1861). 5: Based on peak mining district population (Coroneous, 1995), so likely an over-estimate for the full period. 6: 1881 Queensland census figure. 7: Population estimates from Kirkman (1984, p.55). 8: Productivity per person, based on Kirkman's population estimate. 9: Productivity per miner per day, based on recorded 13,250 total mining population at Palmer goldfield for 1877 in Queensland Department of Mines (1878). 10: Estimate - probably at uppermost end, based on statements by Woodward (1891).

exploited high-grade ground remained. Of course, this fortune was not equally distributed, and many diggers returned from the goldfields either destitute or not having made the equivalent of "wages". Table 1 has representative production and productivity data for the case histories presented.

Although each field was different, placer gold generally dominated early production. Furthermore, a substantial part of that came from non-alluvial placers in the residual, eluvial, colluvial, and hillslope environments. Some fields, particularly Bathurst/Ophir and the Victorian Gold Province, also had substantial early production from conventional proximal placers in defined stream beds, including gravel bars, waterfalls, and canyons; distal placers also became important later in both those fields. Likewise, production extended to perched gravels or buried deep leads in some cases, depending on the weathering history. Of critical importance is that all these environments offered free gold particles and therefore minimal effort in recovery and processing. By contrast, lode and "alluvial clast" gold sources required crushing and grinding which, in the absence of machinery, required the diversion of substantial manpower from mining into processing.

Generally, it was only once the best placers were depleted that the lode sources became significant. This probably applied in most goldfields around the world and can be demonstrated for some, including the famous California gold province (USA), discovered in 1848. In its highest yielding period up to 1860, *"production was practically 99 % from surface placer deposits worked single-handed with limited equipment by sluice methods"* (Hill, 1926 p.173), even though lode mining commenced within two years (Clarke, 1970, p.5) and would eventually dominate production.

In placer-dominated Australian goldfields production typically peaked rapidly, within years or even months, but declined equally fast once the prospective ground was exhausted (though rich ground was commonly re-mined multiple times with decreasing rewards). Furthermore, these high early production rates were commonly extended by "rolling-rushes", whereby new mining areas were discovered nearby, so that their peak production supplemented and then eclipsed the original, only to be overtaken subsequently by yet another, and so on. Understandably, the initial stages in most fields yielded highest daily recoveries per miner. By contrast, average recoveries per miner were lower during peak production, owing to much higher mining populations and intense competition for any remaining unworked ground.

The production profiles of Palmer River and Charters Towers are shown in Figure 3. Palmer River, being essentially a placer field, achieved high production within months and reached peak production within several years, but then faded to obscurity once the best ground was exhausted in the absence of viable lode mines. By contrast, without significant placer gold, Charters Towers achieved a steady but low production from oxidised lodes. Increases only came when large companies consolidated the small leases and introduced capital for the critical de-watering, crushing and milling equipment.

If discovered in Antiquity, essentially all of Palmer River's gold would have been mineable and the rate would have depended mainly on the mining population sustainable in this remote, seasonally-dry and infertile area. Perhaps it would have taken these imagined ancient miners ten times longer to mine out its high-grade areas, but eventually achieving a similar total production. By contrast, if mined in Antiquity, Charters Towers would have yielded only a fraction of its contained gold because most is sulphide ore which would have been too deep below the water table and too difficult to treat, even if accessible with primitive digging implements. No doubt the near-surface oxidised lodes would have attracted attention owing to their sustained high grades, but the field would have produced much less gold and at a much lower rate without iron, steam power, and explosives.

It is also instructive to consider how we might assess the Palmer field in the absence of production records. Our eyes would be drawn to the widespread evidence for diggings on the quartz lodes, and this evidence would survive to some extent even if mining had been in ancient times. We might hazard a guess of production based on spot assays plus the clear evidence for widespread disturbance, given these are hard rocks in a remote area. It is likely we would over-estimate the lode production and certainly there would be nothing to help us conclude that most of the lode mining ventures lost more money than they made. We might also speculate that there would have been some colluvial and alluvial placer production, and this would be bolstered by our ability to pan gold "colours" today in many creeks and on some hillslopes. However, it is unlikely we would contemplate placer gold production at more than twenty times the primary.

Many of the Australian goldfields showed periods of downturn and some had calamitous losses after their initial boom. At least some of that chaos arose from over-promotion, over-population by hopeful miners, and costly import of machinery for deep mining, large-scale ore crushing, mechanical dredging or sluicing before the continuity of the ore had been established. This can yield, as in the Palmer River, conspicuous mining evidence, but from operations that were loss-making. No doubt, there are analogues elsewhere because miners are, by vocation, optimists.

Of course, one might argue that the 19th century miners in Australia benefitted from technology, including iron and steel tools, animal and steam power, explosives, and mercury amalgamation. Whilst all these would confer an advantage over their Bronze Age counterparts, the benefits would be most evident in the later mining phases, for example in the ease of developing and de-watering lode deposits or, conversely, for dredging of downstream "distal" placers. By contrast, these technical advantages would be much less significant in the initial phases, where the equipment was rudimentary, and the critical input was manpower. Arguably, the main effect of the modern technologies would be to increase production rates but shorten the bonanza production period compared to mining in Antiquity.

We must also consider if mining in Australia is in some way different owing to unique features about the climatic and tectonic history. Parts of the continent have been stable, thus minimising physical erosion but facilitating long and repeated lateritic weathering, followed by arid conditions with hypersaline groundwaters, all of which promoted supergene mobilization of gold (Anand, et al., 2019). Amongst the case histories, this applies particularly to the Coolgardie region, where weathering depths are some of the deepest on Earth. Near-surface gold depletion is the norm in this region, which makes the early gold recoveries in this field even more intriguing. However, most of the other regions discussed here have active physical erosion and only moderate chemical weathering at the surface. Thus, it is difficult to identify any feature of these which could mark them as different from goldfields elsewhere in the world (other than the self-evident fact, of course, that mining in Antiquity did not occur in Australia).

A final observation is that early production rates in Australian goldfields bear little correlation with the overall longevity and importance of the field. Ashburton produced at least half of all its known gold in the first six months after discovery, but at a similar rate to the initial stages of the Coolgardie field, which would go on to become part of a world-class gold province. Lisle produced most of its total gold in the first four years, with all deriving from placer sources. Palmer River was predominantly a placer field which rivalled the production rates of Bathurst/Ophir in its heyday years and far exceeded Charters Towers, although the last evolved into Australia's richest major goldfield with semi-continuous production for 80 years.

Perhaps these "flash-in-the-pan" gold districts, with their prodigious early production from colluvial and proximal alluvial placers but short lives, are more common than generally realized. Certainly, the magnitude of initial production from the Palmer River, Lisle, and Top Camp in the Ashburton would be neither known nor predictable in the absence of well-preserved records. This has implications for estimates of earliest gold recoveries elsewhere, within regions first discovered and mined during times for which records no longer exist. For example, the New Kingdom Egyptians, after their expansion into the southern part of the Eastern Desert of "Nubia" (southern Egypt and northern Sudan) would have encountered extensive and productive gold-bearing areas with effectively no prior mining activity (Klemm and Klemm, 2013). They would have been the "first movers". Perhaps it is worth reassessing the likely production and mining methods in this period, from the perspective of Australian deposits as outlined above. The same applies to early mining phases in other important gold regions like the Balkans, Carpathians, and Caucasus.

Conclusion

This paper demonstrates the substantial rewards available to discoverers of gold deposits that have not been mined previously, as evidenced by some uniquely well-documented Australian discovery histories. The bonanza that many of these yielded in their initial phases conceivably had analogues in other parts of the world, but where earliest mining was in Antiquity, leaving minimal information in either the archaeological or the documentary record.

In many (perhaps most) goldfields, early production is dominantly free particulate gold from placers, including both proximal alluvial and colluvial environments. However, manual placer mining leaves almost no long-lasting record on the environment and hence its significance is almost impossible to assess without documentary evidence.

Therefore, historians and archaeologists working within gold regions that have been reworked multiple times since Antiquity might benefit from considering the Australian perspective, where clear records exist of the productivity that can be achieved by the "first-movers" into new gold districts. Unless technology improvements gave them a boost, all subsequent mining campaigns were only accessing the spurned leavings of these first and generally unrecorded campaigns.

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Note

1 Dwt is an abbreviation of pennyweight, 1/20 of a troy ounce.

2 This equates to about 15 grams of gold per tonne.

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