Australian Institute of Geoscientists

AIG NEWS

Quarterly Newsletter No 97 August 2009

Stratigraphic Controls on Structures and Mineralisation in Central Victoria 5: Nerrina

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Abstract

This is the fifth in a series of papers discussing the stratigraphic controls on structures and gold mineralisation in Victoria. The Nerrina (or Little Bendigo) goldfield is the northern third of the Ballarat goldfield. However, despite being practically along strike from the Ballarat East goldfield, the stratigraphy, structures and quartz veining at Nerrina are completely different. The tight folding at Ballarat East is not seen at Nerrina. Instead the entire goldfield lies on a broad west-dipping fold limb. This limb is devoid of significant faults, unlike Ballarat East where west-dipping and crosscourse faults are common. Quartz at Nerrina is stratabound within shales 2-25m thick. Such shales are virtually absent at Ballarat East. The mineralisation within the west-dipping shales continues well below the historic workings. Only 3% of more than 1,000 mapped shafts have recorded production. While historic records show that only 120,000 oz of gold came from the Nerrina goldfield, the vast alluvial workings and large number of primary workings suggest that this grossly underestimates the gold endowment of the area. The alluvial workings link to major deep lead systems flowing southwards into Ballarat and northwards into the Berry leads system that produced 1.7 Moz of gold. The well-rounded and spherical quartz on the Berry dumps can be traced back to Nerrina, but it is uncertain how much of the alluvial gold can too.

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Introduction

Central Victoria is a world-class orogenic gold province where faults and folds within Ordovician turbidites host gold and associated mineralisation. Such turbidites occur across most of Victoria and in the field comprise monotonously interbedded sandstones and shales, although facies variations and lateral discontinuity of individual beds are characteristic at a local scale. This study of Nerrina (Fig. 1) follows reviews of Bendigo, Ballarat East, Fosterville and Lockington by Boucher *et al.* (2008a, b, c, d).

The Nerrina (or Little Bendigo) goldfield was intensely worked for alluvial and reef gold. However, the majority of this work occurred in the 1850's and 1860's and there are virtually no records.

Figure 1. Location map showing turbidite-hosted gold deposits discussed in this series of papers.

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32 primary workings are recorded in the Geological Survey of Victoria's database, however over 1,000 shafts have been mapped in the field. The 120,000 oz of reef gold quoted for Nerrina probably grossly underestimates production from the area. Outcropping quartz reefs originally stood to just over 3 m high and could be traced for several hundred metres along strike (Whitelaw, 1901). Production came from numerous lines, but most of the mining occurred within the Dimocks Main Reef (Figs 2-4) and the Monte Christo Reef (Figs 2 & 4). These reefs are 550 m apart on the west limb of the Monte Christo Anticlinorium.

The Nerrina tenements are held by a private company, North Ballarat Pty Ltd, which embarked on an intensive field mapping campaign to accurately survey the positions of the shafts and alluvial workings. This work enabled the geological controls on mineralisation to be established and these were confirmed by diamond drilling in 2008.

As at Fosterville and Lockington, no attempt has yet been made to formally name stratigraphic units at Nerrina. Instead a coded numbering system has been used to identify units (Fig. 3). The Nerrina units surrounding the Dimocks reefs are given the prefix 'DI', with thick shales denoted 'SH' and amalgamated channel-sands 'CH'. The 'shale-topped sands' (STS) above and below the channel-sands are designated 'TS' and 'LS' respectively. A package from the top of a shale to the top of the next shale above is considered analogous to a formation and is assigned a number for the combined LS/CH/TS/SH facies (Fig. 3).

Gold workings at Nerrina and in the surrounding region

Field mapping has revealed over 1,000 primary workings and a significantly larger number of alluvial potholes plus intensely sluiced gullies up to 10 m deep and 100 m wide (Fig. 2). Over 90% of workings were too shallow to reach the water table at 30 m and only 18 shafts are considered to have exceeded 100 m depth. About half of the larger shafts have some written records, but only two brief geological summaries have been written (Whitelaw, 1901; Bradford, 1904). Given the paucity of recorded data, a great deal was revealed by detailed field mapping of the tenements. The continuity of the workings and the geological information in the open shafts, small open cuts and adits revealed that quartz veining occurs mainly within west-dipping shales. Aside from minor parasitic folding and some very small faults with displacements of less than a metre, few structures were seen at the surface. The most significant shale, the 25 m thick 'Dimocks Main Shale', contains veins aligned on bedding and cleavage and an enormous tonnage beneath the shallow workings.

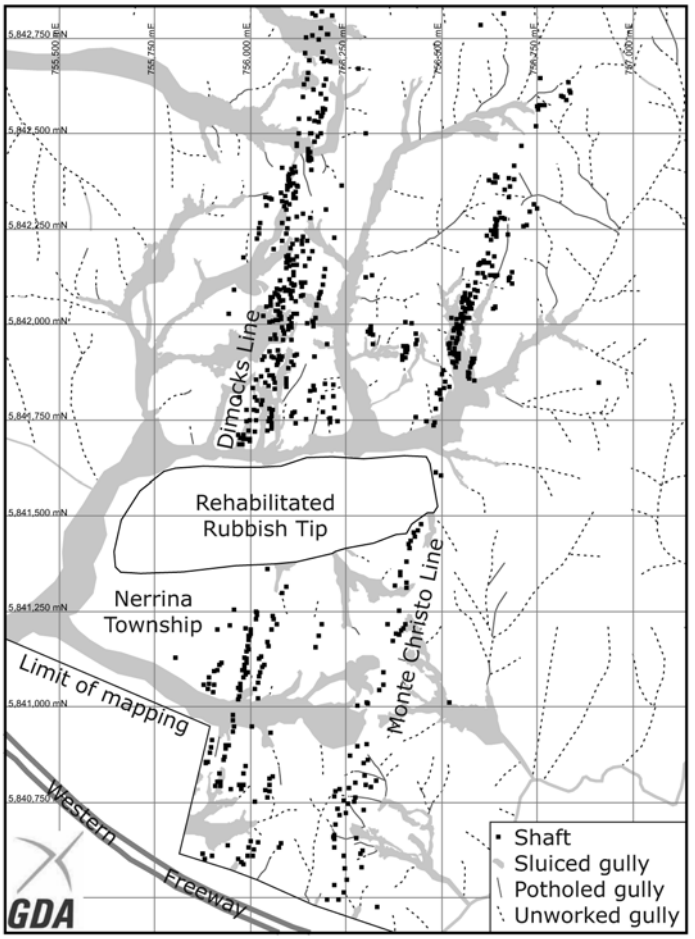

Figure 2. Gold workings near the Nerrina township. Primary workings form two continuous bands punctuated by cultural features and alluvial cover. The alluvial workings provide good vectors to the primary mineralisation

Recorded grades are rare, but some production at a grade of 13.7 g/t was reported from the Dimocks Line. Drill intercepts up to 170 g/t occur.

The alluvial workings provide good vectors to the primary mineralisation (Fig. 2). There is excellent correlation between the upstream limits of the alluvial workings and the reef positions. These data are valuable in understanding the geology of the main reefs and confirming that there was significant up-dip eroded gold mineralisation within the thick shales. This gives extra confidence in the likelihood of gold endowment down-dip.

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The leads shown in figure 2 flow towards the southwest and combine with material eroded from the Ballarat East and Ballarat West goldfields to form the rich shallow and sub-basaltic alluvial deposits that produced 11 Moz of gold. To the north of the area shown in figure 2, a series of older leads are preserved adjacent and sub-parallel to the present drainage system. Up to six older leads are preserved on adjacent terraces. To the north these leads converge into the Berry leads system that produced 1.7 Moz of gold. Well rounded and spherical quartz makes up almost all the clasts found on the mine dumps along the Berry lead, over 20 km from Nerrina. Boucher (2009) demonstrated that the quartz clasts can be tracked back the entire length of the lead to Nerrina. While the quartz appears to have been transported this distance, it is uncertain how much of the gold has. There are new quartz populations appearing in the leads from time to time and large nuggets were found within the alluvials that are unlikely to have been transported far. Yet gold is known to be transported considerable distances in central Victoria. Alluvial gold was worked at Huntly, 20 km downstream from the Bendigo goldfield.

Nerrina stratigraphy

The best exposures occur within adits and sluiced gullies along the Dimocks Line (Fig. 2) and the mapped stratigraphy (Fig. 3) was confirmed by diamond drilling in 2008. The Dimocks stratigraphy is dominated by thick shales, the largest being the 'Dimocks Main Shale' which reaches 25 m. While this is not as thick as some of the shales seen at Fosterville (Boucher *et. al.*, 2009c) or Bendigo (Boucher et. al., 2009a), it is thicker than any shale units in the Ballarat East goldfield immediately to the southwest. The 'Big Slate' that reaches 15 m in the northern part of the Ballarat East goldfield (Boucher *et. al.*, 2009b) and may be a potential candidate for correlation.

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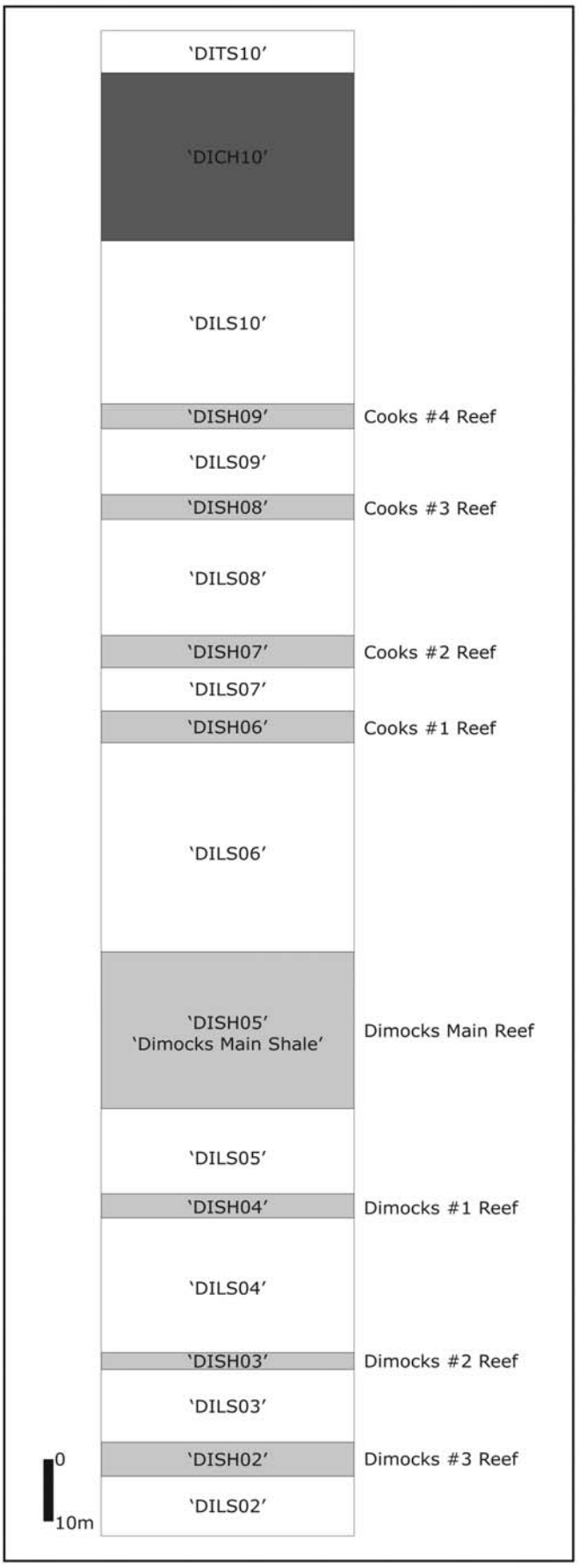

Figure 3. Stratigraphic column highlighting thick shale units (pale grey), channel sands (dark grey) and major quartz reefs.

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Below the 'Dimocks Main Shale', the stratigraphic succession is shale dominated. In between the thick shales, the STS are dominated by shales with interbedded fine- and very fine-grained sands. In contrast, the STS above the 'Dimocks Main Shale' are sand dominated, reaching medium-grained size.

Genuine channel sands occur at the top of the stratigraphic succession shown in figure 3. Unlike the 'Big Sandstone' at Ballarat East that is medium-grained (Boucher *et. al.*, 2009b), 'DICH10' consists of coarse- and very coarse-grained sandstone.

Stratigraphic controls on the development of veins, faults and folds

Bedding-parallel, laminated quartz veins are absent at Nerrina, despite the prevalence of thick shales that are good hosts for such veins at Bendigo, Fosterville and Lockington. Instead, massive quartz veins occur parallel to bedding and on axial-planar cleavage in the thick shales. As a result, it is common to see the 25 m thick 'Dimocks Main Shale' containing a network of west-dipping and upright veins averaging 10% of the width of the shale.

The Cooks reefs are stratabound, boudinaged, massive quartz veins within shales separated by sand-dominated STS. In contrast, the Dimocks #1-#3 reefs contain bedding-parallel and cleavage-parallel veins. The latter commonly take a sinusoidal path through adjacent sandstone beds, as demonstrated by Boucher *et. al.* (2009a).

Diamond drilling in 2008 revealed that the gross geometry of the west-dipping shales inferred from surface mapping holds true. However, some west-dipping faults were found to ramp from bedding-parallel positions within a thick shale and transgress the adjacent STS package before returning to a bedding-parallel position in an overlying thick shale. The exact nature and significance of these faults is undergoing evaluation. Additionally, small east-dipping faults occur. These usually have displacements of less than a metre but often contain quartz and are significantly mineralised.

The Nerrina goldfield was worked prior to the development of the large underground mines at Ballarat East and so predates the concept of 'indicator beds' (Boucher et. al., 2009b). As a result, there is no discussion of 'indicators' in the Nerrina literature with the exception of Whitelaw (1901) who shows flatmakes on the Monte Christo Line (Fig. 4) intersected by the Jarvis Indicator.

Folding and fault styles at Nerrina

Unlike Ballarat East where tight, upright to overturned chevron folds occur, Nerrina occurs on the broad west limb of the Monte Christo Anticlinorium (Fig. 4), although the data in between the main worked zones are sparse. Dips tend to shallow towards the west and are as low as 50° in the 'Dimocks Main Shale'.

Faults are rare and mostly small. Small east-dipping faults, usually with displacements of less than a metre were found in adits and from

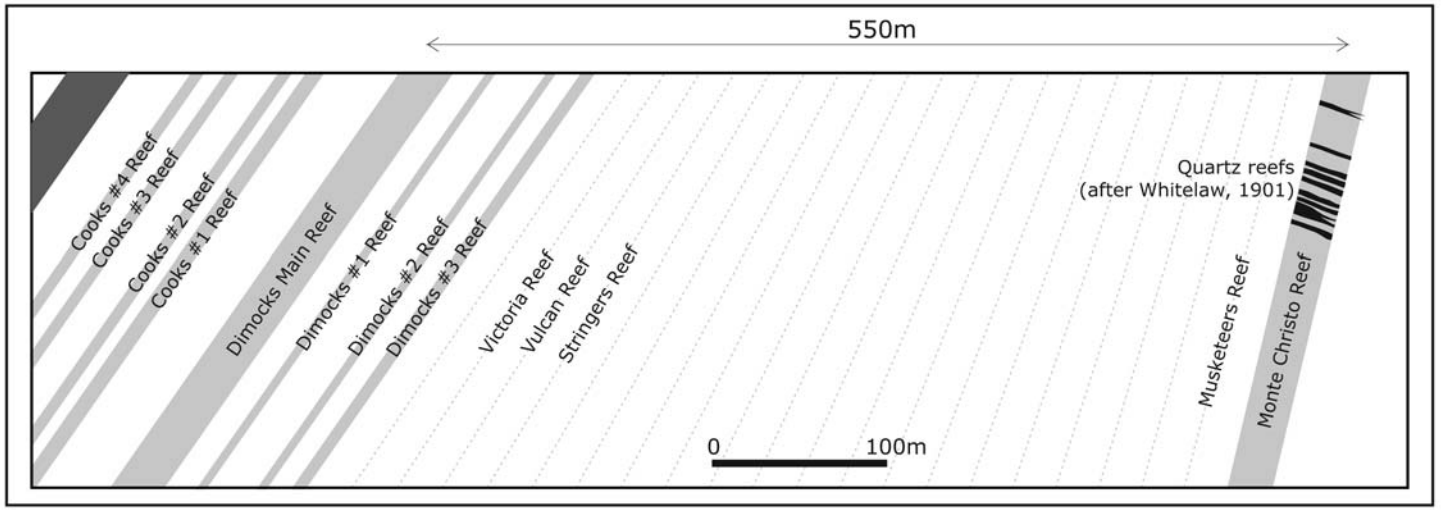

Figure 4. Cross section through the Nerrina goldfield showing the positions of the reefs within the thick shale units (Fig. 3). Quartz reefs depicted by Whitelaw (1901) are shown at the top of the Monte Christo Reef.

diamond drilling. West-dipping faults of uncertain displacement were interpreted from the drilling. These faults are bedding parallel in the thick shales, but ramp up through overlying STS before returning to a bedding-parallel position in an overlying shale. Small crosscourse faults were described in the literature and observed in field mapping. These are usually discrete faults with only a few metres of displacement. Minor parasitic folding occurs within the main west limb, but this is very rare.

Conclusions

The Nerrina goldfield contrasts remarkably with the Ballarat East goldfield immediately to the southwest. Quartz veins at Nerrina are stratabound within thick shales on a broad west-dipping fold limb that is otherwise devoid of major structures. In contrast, Ballarat East lies within a tightly folded and faulted sandstone-dominated succession. Despite the sandstone dominance at Ballarat East, the sands only reach medium grain size whereas they can be very coarse-grained at Nerrina. While the workings at Nerrina are continuous along strike over significant distances, they are mostly shallow and the mineralisation is open at depth. Where the shales are large, such as the 25 m thick 'Dimocks Main Shale', they provide an enormous tonnage target. This differs markedly from the majority of Victorian goldfields where the targets are narrow targets and of restricted height. Nerrina provides a new type of target for Victoria that may not demand the high grades required elsewhere.

Careful field mapping has been integral to understanding the Nerrina goldfield as the existing data were not sufficiently detailed to understand the geology. Mapping of alluvial workings revealed the vectors to the gold source and demonstrated that high volumes of gold had been from eroded, up-dip shale positions. The quartz from Nerrina can be followed as far as the Berry leads system over 20km to the north. It is uncertain how much of the 1.7 Moz of gold mined from the Berry leads came from Nerrina. Likewise it is uncertain how much of the 11 Moz of alluvial gold at Ballarat was sourced from Nerrina. ▲▲

Acknowledgements

This paper is published with the permission of North Ballarat Pty Ltd which has enthusiastically encouraged the detailed mapping necessary to interpret the Nerrina geology and mineralisation. Thanks go to Allan Rossiter for assistance with the final editing.

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