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STRATIGRAPHIC CONTROLS ON STRUCTURES AND MINERALISATION IN CENTRAL VICTORIA 4: LOCKINGTON

Abstract

This is the fourth in a series of papers discussing the stratigraphic controls on structures and gold mineralisation in Victoria. Mineralisation was discovered beneath the Murray Basin at Lockington in 2005. Lockington has a shale-dominated succession with more shale than at any other location discussed in this series. Like Fosterville and Bendigo, Lockington has linked systems of shale-hosted laminated quartz veins and thrusts that propagate from fold hinges and truncate fold limbs. However, Lockington also has shallow west-dipping faults that are pervasive and cross both limbs of folds in a similar fashion to that seen at Ballarat East. These tend to be the faults that host Fosterville-style mineralisation. Lockington shares a mixture of fault styles seen at Bendigo, Fosterville and Ballarat East. While numerous gold intersections have been encountered during drilling at Lockington, a major structural host to economic mineralisation is elusive.

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 Lockington (Fig. 1) follows a review of the Bendigo, Ballarat East and Fosterville goldfields by Boucher *et al.*, (2008a, b, c).

It has long been tantalising to explore for a world-class orogenic gold deposit under the shallow Murray Basin sediments north of Bendigo, Fosterville and St Arnaud. However it was not until late 2003 that Gold Fields Australasia Pty Ltd commenced a concerted effort to explore a 5,000 km^2 area north of Bendigo. Initially, geophysical structural interpretation and depth to basement modelling using water bore data delineated zones of interest. Soil geochemical work identified gold and silver anomalies south of Lockington and traverses of air core holes were drilled to sample the top of the Ordovician basement at 70 to 100 metres depth. This work delineated seven parallel trends mineralised in gold, arsenic and antimony, three of which were selected for diamond drill testing in 2005. The longest trend (at Lockington East) extends for 9 km and is open at both ends. A total of 31 diamond holes have been drilled to 500 m downhole into these three trends over a strike length of 2 km at Lockington South, and on two sections

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

INSIDE THIS AIG NEWS:

Stratigraphic Controls on Structures and Mineralisation in Central Victoria 4: Lockington

Cont. from Page 1

3 km apart at Lockington East. Fosterville-style mineralisation was intersected in the first hole and provided an impetus for exploration. From the first hole, detailed sedimentological and structural logs were constructed and utilised to generate subsequent drill targets. Mindful that each turbidite-hosted gold deposit in central Victoria occurs in a different structural setting (as demonstrated by Boucher *et al.*, 2008a, b, c), drill targeting was model-guided rather than model-driven and continually sought the ingredients unique to Lockington.

As at Fosterville, no attempt has yet been made to formally name stratigraphic units at Lockington. Instead a coded numbering system has been used to identify units (Fig. 2). Lockington successions are given the prefix 'LO', thick shales are denoted as '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. 2).

Stratigraphy-guided drill targeting

The first diamond hole at Lockington, LODH001, passed through 90 m of Tertiary Murray Basin sediments before intersecting 170 m of west-dipping Ordovician turbidites. LODH001 encountered units LOSH22 through to LOLS16 (Fig. 2) on the west limb of the Friesian Anticline (Fig. 3). Patchy Fosterville-style mineralisation (up to 7.7 m @ 4.24 g/t) occurred within STS down the hole. It is rare to get good mineralisation on west limbs at Fosterville and prospectivity was considered to be high at Lockington if a structural site equivalent to the Phoenix Fault could be found. Numerous thick shales with bedded laminated quartz veins were intersected in LODH001. It was hoped that these would act as a guide to mineralisation where they crossed folds, as seen at Fosterville and Bendigo. At Fosterville, the best mineralised faults are linked to laminated quartz veins hosted by thick shales above synclines (Boucher et al., 2008c). LODH002 and LODH006 were drilled to the west of LODH001 but failed to locate a syncline. The west-limb beds are almost vertical (Fig. 3) and given that the syncline had not been located, this target model was deemed too deep to justify drilling.

Later drilling to the east located the Friesian Anticline and Syncline. Based on the Fosterville model, prospective positions were drilled but

Cont. on Page 4

Stratigraphic Controls on Structures and Mineralisation in Central Victoria 4: Lockington

Cont. from Page 2

no significant mineralisation was located, demonstrating that even though the mineralisation at Lockington is similar to that at Fosterville, its structural setting is different. Mineralisation is usually found in shallow west-dipping reverse faults similar to those seen at Ballarat East (Boucher *et al.*, 2008b). Most of the 31 holes drilled so far intersected significant mineralisation.

Lockington stratigraphy

Most of the drilling has been along the Friesian Anticline where a stratigraphic succession 350 m thick has been identified (Fig. 2). Thick shales dominate the succession and there is significantly more shale at Lockington than at Fosterville, Bendigo and Ballarat East. Channel sands occur near the top of the succession. Almost all shales contain significant bedding-parallel, laminated quartz veins, however the continuity of these is not known. Similarly, there has not been enough drilling to ascertain variations in stratigraphic thickness as have been established at Fosterville and Bendigo.

The thicker shales (LOSH14, 17 & 20) host bedding-parallel laminated quartz veins that control the main linked fault systems. There are not enough data at this stage to demonstrate how many thrust fault systems propagate from the bedding-parallel faults and it is possible that they all do.

Stratigraphic controls on the development of veins, faults and folds

Bedding-parallel, laminated quartz veins are common at Lockington within thick shale hosts. Stockwork quartz occurs close to major faults and is especially well developed in sand units.

Mappable linked faults occur between bedding-parallel laminated quartz veins within LOSH14 and LOSH17, and also between LOSH14 and LOSH20 (Fig. 3). There are not enough data to ascertain if faults propagate from other laminated quartz veins. The linked fault style is similar to that seen at Fosterville and Bendigo. Like Fosterville, the thicker shales generate the largest faults - although the fault displacements at Lockington reach only 20 m whereas the key faults at Fosterville have 150 m displacement.

A second series of faults is west-dipping and crosses both fold limbs, similar to the situation seen at Ballarat East (Boucher et al., 2008b). These faults tend to be mineralised. They often have only a couple of metres of displacement which can be detected solely by detailed stratigraphic mapping revealing one or two faulted-out beds. STS successions are mineralised where crossed by such faults, whereas the thick shales are not usually. Targeting of these structures is difficult given the large volume of thick shales in the overall succession. It is probable that west-dipping faults offset all other structures and are younger than the folds and the main linked-fault system, although more data are needed to confirm this. It is likely that there are significantly more of these faults than shown in figure 3. Only LODH006 and LODH022 intersected channel sands cut by an interpreted west-dipping fault.

Based on Ballarat East, this should be a good structural site for mineralisation. LODH006 intersected 2.0 m @ 2.47 g/t in this position and LODH022 similarly intersected 2.5 m @ 4.17 g/t indicating a target worthy of further drilling.

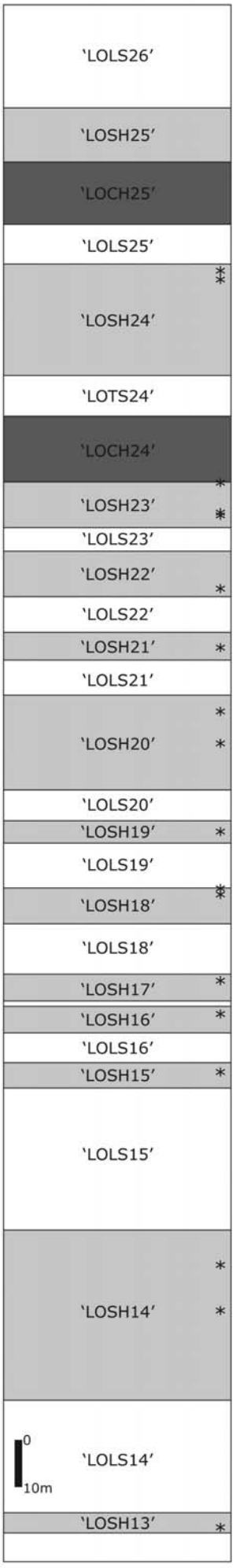

Figure 2. Stratigraphic column highlighting thick shale units (pale grey), channel sands (dark grey) and major bedding-parallel, laminated quartz veins (*)

Folding and fault styles at Lockington

The Friesian Anticline and Syncline (Fig. 3) are upright chevron folds with interlimb angles of 30° and 40° respectively. A domal structure culminates within the drilled area and hinge lines plunge gently to the north and south. To the east, the Holstein Syncline is a steeply inclined open fold with an interlimb angle of 80 o to 90 o and where drilled is plunging gently to the south.

Lockington has linked fault systems similar to those seen at Fosterville and Bendigo plus pervasive west-dipping faults like those at Ballarat East. It has been proposed that the lack of thick shales at Ballarat East allowed folds to be tighter than at Bendigo (Boucher *et al.*, 2008b) and therefore faults crossed bedding rather than slipping along it. At Lockington, it appears that bedding-parallel slip occurred in the early stages of folding, represented by laminated quartz veins. It is likely that once the west limb of the Friesian Anticline approached a vertical orientation, faults propagated across the limb rather than along bedding. The west-dipping faults tend to be the mineralised and are likely to be the latest faults.

Conclusions

Gold is present at Lockington in Fosterville-style fine-grained disseminated arsenopyrite mineralisation. Linked faults propagating from laminated quartz veins within thick shales similar to those found at Fosterville and Bendigo occur here. However, these tend not to be mineralised. Low-displacement, pervasive west-dipping faults like those at Ballarat East are present as well. These faults are probably younger and host the majority of the mineralisation. Only 31 diamond holes have been drilled at Lockington on broadly spaced sections. While economic gold-bearing structure(s) have yet to be recognised, the number of gold intersections and the volume of the unexplored area indicate there is plenty of potential for a major deposit.

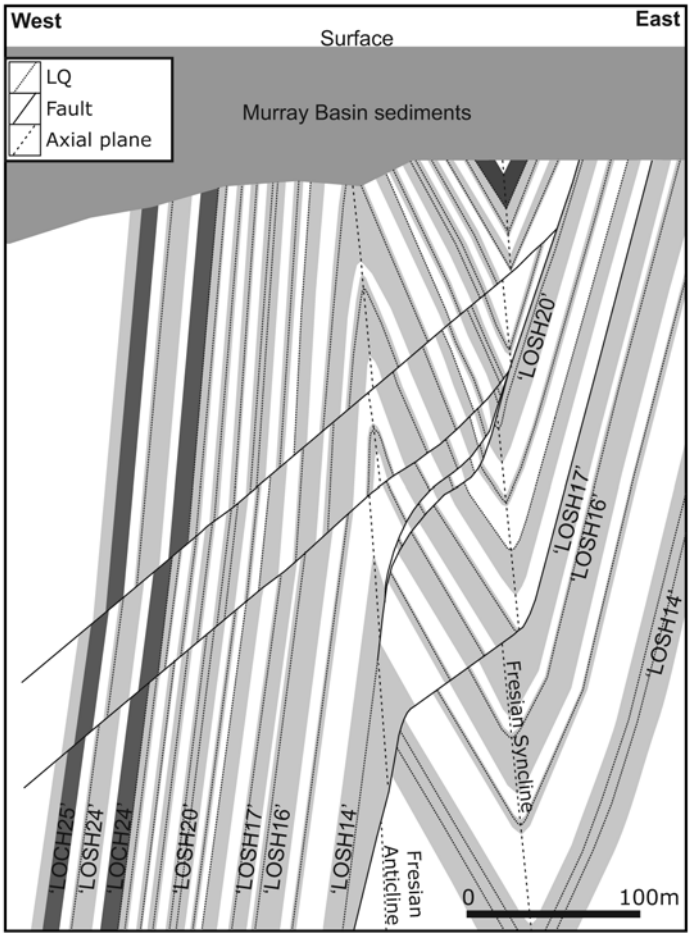

Figure 3. Section 5981900mN showing major shale and channel-sand units, key faults and laminated quartz veins (LQ's).

Acknowledgements

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From Your President

Cont. from Page 3

representative public voice for geoscientists rank amongst the most important. The current status of this proposal is that there have now been several meetings to discuss the proposition and the form that the merged entity would take. It is no simple task to effectively merge two very different organisations while building on the best attributes of each organisation in creating an even better one. At present, both AIG and GSA are seeking independent advice on the legal processes required for a merger, which will be completed prior to representatives of both organisations meeting, probably in the new year, to decide on the feasibility of the proposal and whether to proceed with developing a detailed proposal and plan to be considered by both AIG and GSA members. It goes without saying that AIG members will be kept fully informed and will be able to participate in the process, and be provided with the information needed to make an informed decision should any decision to proceed be made.

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