Utilising Sediments to Constrain the Structural Reconstruction of the Central Victorian Goldfields

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Abstract

To build a geological interpretation, marker beds are needed to determine fold and fault styles and displacement. Unfortunately, the monotonous interbedded sands and shales of central Victoria are difficult to correlate. However, detailed sedimentological studies utilising new depositional models are increasing the geological understanding of the goldfields of central Victoria. Detailed geological sections can be constructed to delineate structural and lithological mineralised targets and to better understand vein generation.

Introduction

There have been major advances in the understanding of deep marine sediments as a result of petroleum exploration in the USA over the last few years. Using this knowledge, the writer has carried out a series of projects to map turbidites in the goldfields of central Victoria. Initial work began as student practicals, assignments and projects in the final years of the geology degree at La Trobe University, Bendigo. Work has gained momentum since the writer started work with Bendigo Mining NL and Perseverance Corporation Ltd in 2001. Sedimentary logging and mapping procedures have been adopted by both companies and stratigraphic studies are integral to daily mine operations.

Bendigo is Victoria's largest producing goldfield, and lies 150km NNW of Melbourne. Perseverance Corporation Ltd's Fosterville goldfield lies within a large under-explored mineralising system 20km NE of Bendigo. The two areas have contrasting structural and mineralisation styles but are both hosted within turbidites.

The importance of stratigraphy

Mines with highly variable lithologies might take for granted the importance of a definable stratigraphy. Marker horizons are crucial to determine fold geometry and position, especially when the hinge area is obscured or faulted. Marker beds constrain fault widths, styles and displacement. Ultimately these data are needed to piece together the geology jigsaw. Figure 1 demonstrates how one marker horizon is important to determine the style and magnitude of displacement of a fault. Alone, a fault found in drill core has little meaning if the offset cannot be determined. Conversely, the position and offset on faults can be determined by correlating the stratigraphy in two drill holes if for some reason the fault was overlooked. Where stratigraphic units are missing or added, then either facies have changed or a fault is suspected.

Areas with well-defined stratigraphy may enable a full geological reconstruction to be made. However, in central Victoria there are few marker beds or distinguishable units to use. Palaeontology has been used with some success to define broad successions, but, greater resolution is commonly needed when working in a mine.

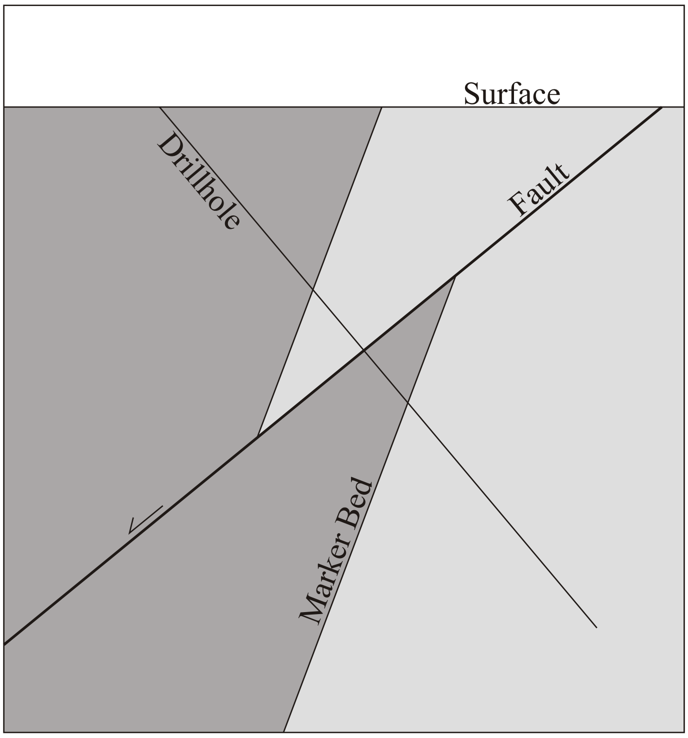

Figure 1. Joining marker beds is a simple method to produce a valid structural interpretation. Without the marker bed, it is not possible to determine the amount of offset on the fault.

The rocks of central Victoria and how they correlate

The deep marine sediments in central Victoria are a monotonous succession of interbedded sandstones and shales. There are no unique limestone or ash beds to assist mapping, and attempts to correlate between drill holes or outcrops have proved difficult as a result. The average bed thickness of sandstones in central Victoria is thirty centimetres, and traditional mapping on a regional scale does not provide an appropriate level of detail to correlate beds. Moreover, the central Victorian gold deposits are normally mapped by geologists whose mining background may not provide the necessary expertise to interpret the sedimentary host rocks.

Major changes in logging practices at Fosterville and Bendigo have seen broad-scale lithology interpretations superseded by detailed sedimentary logs. Figure 2 (overleaf) is an example of composite stratigraphic logs derived from several drill holes on three sections from Bendigo, where it has proved important to distinguish very coarse, coarse and medium grained sands from fine and very fine sand-dominated successions. Also, it has been found to be important to distinguish successions of fining upwards and thinning upwards beds from those which coarsen and thicken upwards. These distinctions have enabled rapid and accurate correlations to be made.

Deep marine depositional processes

Studies in sedimentary geology, mostly from the US petroleum

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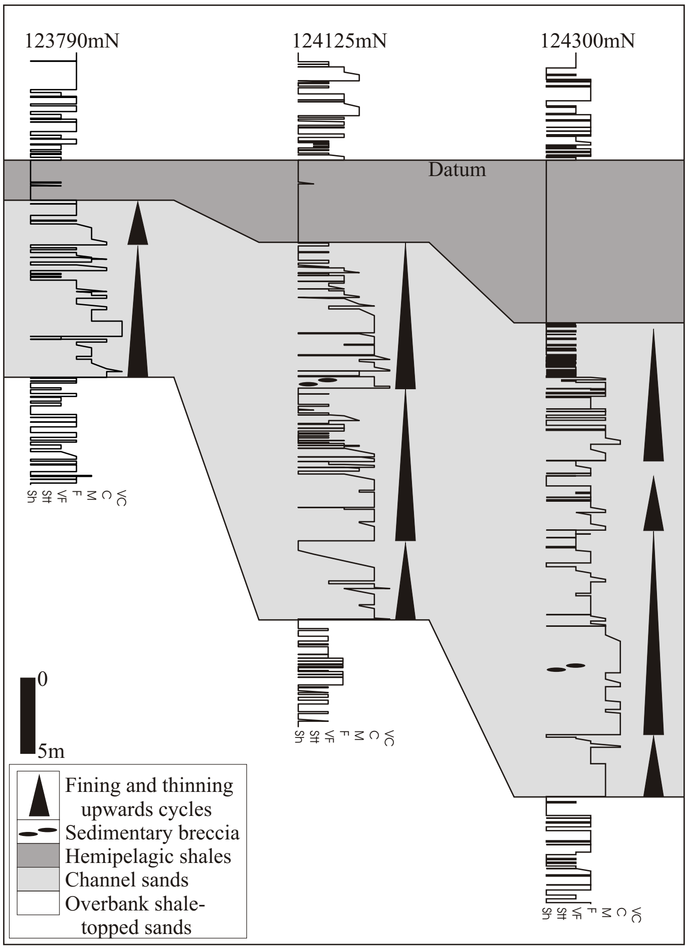

Figure 2. Correlation of composite stratigraphic logs from three Bendigo Mining NL drill sections. Both the shale and the channel sands thicken to the north but the channels climb stratigraphy to the south. Above and below the shaded facies are thick successions of shale-topped sands. The Y-axis is true thickness converted from drilled thickness. The X-axis is grain size. Northings are BMNL mine grid.

industry, have greatly increased our understanding of deep marine depositional processes in recent years. Significantly, broad meandering channels on the modern ocean floor have been identified.

Paleo-channels similar to these modern features are recognisable in outcrop in central Victoria as amalgamated coarse sand facies. Adjacent to channels, overbank sands are deposited. They are characteristically fine and very fine grained, and are usually interbedded with thin shales - they are colloquially referred to as "shale-topped sands". As a general rule, with an increase in distance from a channel there is an increase in hemipelagic shale in the succession.

Results from Bendigo Mining NL

Recent delineation fan drilling by Bendigo Mining NL, comprising up to fifteen holes to 100 metres in length radiating from a single point, provides an excellent detailed data set for correlation and interpretation. High resolution stratigraphic logging has accurately defined fold positions, fault planes, zones and offsets, and enabled detailed lithological correlations.

Figure 2 shows the facies changes over 500 metres defined from delineation drilling from the decline. The hemipelagic shale ("Wescott Shale") is four times as thick to the north and the channel sand sequence ("Trew Grit") is almost three times as thick. There are at least four fining upwards cycles in the channel sands to the north, decreasing to two in the south. Channel sands and thick shales are important marker units because normally shale-topped sands will dominant a succession. Having a thick shale directly overlying channel sands (Fig. 2) provides a uniquely identifiable combination.

An increase in understanding of vein formation was an unexpected bonus that has arisen from detailed stratigraphic mapping. The increase in stratigraphic detail has revealed the extent of the lithological controls on vein orientation. Veins in sandstones, historically referred to as spurs in central Victoria, are commonly perpendicular to bedding, whereas sparser veins in shales tend to parallel the axial planes of folds. These veins probably exploit cleavage planes in the respective lithologies. When the background cloud of "cleavage" veins is removed from a section, the clusters of veins of other significance are highlighted.

The channel sands in Figure 2 host a series of gold bearing quartz veins on the limb of the Sheepshead Anticline. Part of the current exploration program focuses on veins in this position, rather than more traditional axial plane targets. Veining and associated gold is most prolific in the central section in Figure 2. Veining diminishes to the south where the coarse sand component decreases, but also diminishes to the north where the coarse sand increases. Studies are continuing to relate vein intensity to sedimentary facies.

Results from Perseverance Corporation Ltd

In contrast to Bendigo, the gold at Fosterville occurs in disseminated sulfides and not as free gold in quartz veins. Faults predominantly host the mineralisation at Fosterville, whereas anticlinal axes are the dominant controls at Bendigo. Moreover, exploration is less advanced at Fosterville than at Bendigo: the present Fosterville resource was defined from 50m and 25m spaced drilling, and it will probably not be until 2005 that the decline is sufficiently advanced for delineation fan drilling.

Prior to any stratigraphic studies, the position of the Phoenix and Fosterville Faults (Figure 3) was well understood and mapped. There was good understanding of the hanging wall stratigraphy immediately above the Fosterville Fault, especially where exposed in the open pits. Stratigraphic studies have been used to constrain the model and increase the level of confidence in it, extend the model to new areas, and assist with drill planning.

A significant observation by company geologist Max Shawcross was that the stratigraphy in the hanging wall was repeated either side of the Sandhurst Fault (Figure 3). The mechanism for repetition is not clear, and one interpretation is that NNE-directed thrusting is the cause. Mapping by Solid Geology Pty Ltd has

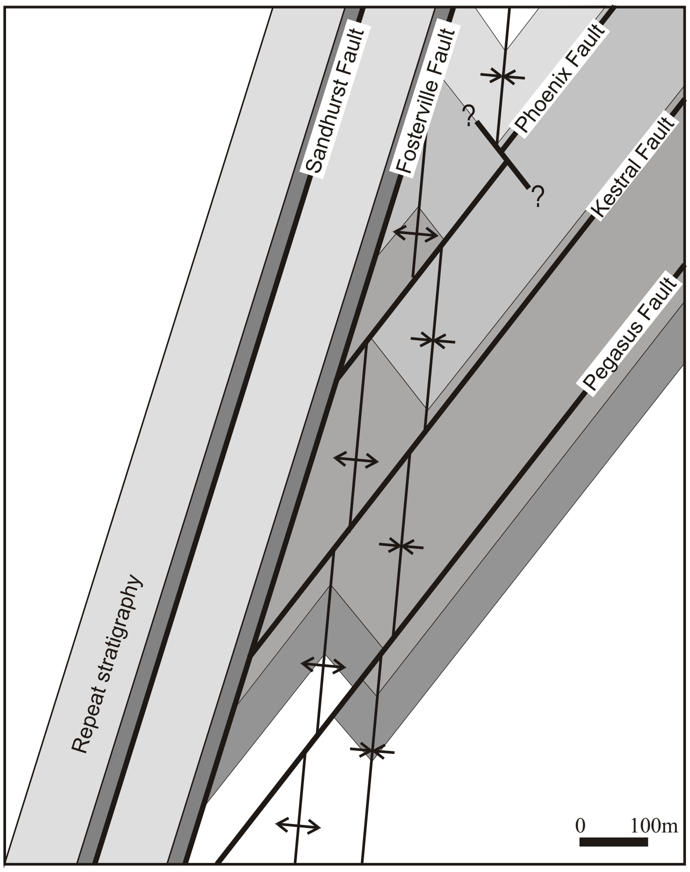

Figure 3. Schematic section of the Perseverance Ltd Fosterville mine. Mining is commencing around the Phoenix and Fosterville Faults. Exploration is underway on the Kestral and Pegasus Faults.

demonstrated the fault converges with the Fosterville Fault towards the southern end of the lease.

The synclines above and below the Phoenix Fault (Figure 3) have long been thought to be the same structure. Stratigraphic mapping has shown that the west limb of the syncline below the Phoenix Fault matches the east limb of the syncline above the fault. This confirms the vertical displacement of the axial plane and therefore the offset on the Phoenix Fault. Stratigraphic mapping has revealed the Phoenix Fault is offset near the hinge of the hanging wall syncline. Up to 40 metres of displacement occurs on an east dipping fault (Figure 3). Mineralisation on the Phoenix Fault is capped by a thick shale in the hinge at this point.

New deeper exploration is targeting the east limb of the anticline on the Kestrel and Pegasus Faults. Stratigraphic logging has confirmed the position of the anticlines and the offset on the faults. The overall stratigraphy has now been built to below the Pegasus Fault. Further work is underway to check on a potential repeat section that is suspected between the Phoenix and Kestrel Faults.

The research to date has shown that there is no match between the stratigraphy on either side of the Fosterville Fault, and the amount of offset on that structure remains to be determined.

Conclusion

Recent studies by US petroleum geologists have provided new insights into deep marine sedimentary processes. Utilising this knowledge in conjunction with detailed field mapping and core logging, it has been possible to successfully correlate stratigraphy and reconstruct structural features to produce quality geological interpretations. This has helped interpret exploration sections at Fosterville, and detailed delineation drilling at Bendigo. From this work, fault positions, styles and offsets are determined in addition to fold geometry and positions. The increased understanding and confidence in the geological model enhances target delineation and drill planning. Better understanding of the geological model increases the understanding of other features, such as quartz veining and its relationship to cleavage orientation.

Acknowledgements

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