

## Introduction

Western Victoria is host to several world class sediment-hosted gold deposits (e.g. Stawell, Ballarat, Bendigo) that have been studied on an individual basis, generally without reference to a well-constrained regional structural and stratigraphic framework. The configuration and availability of fluid conduits (shear zones or other structural settings and appropriate host lithologies) over time is clearly an important factor in the formation of these mineral deposits but the distribution and profiles of fluid pathways with increasing crustal depth are often imprecisely known. It is also probable that the mineralising fluids were not locally sourced, but travelled long distances from their point of origin, making it imperative that all potential fluid conduits be mapped in 3D so that any sub-surface linkages or networks of fluid pathways be identified. These pathways then need to be incorporated into the 3D regional framework so that the key conduits and structures can be further investigated to establish their precise role in either controlling or sustaining fluid flow over geological time scales appropriate for the formation of a major ore-body. The Stawell Zone in western Victoria is ideally placed for such a case study because it contains sequences that relate to the mineralisation types found in Tasmania and those identified in central Victoria and NSW.

## High Impact Outcomes

- Established absolute timing relationships in the Stawell Zone (in collaboration with H4)
- Structural analysis of the setting of mineralisation in the Stawell Gold Mine
- Reverse engineering of the structural evolution and fluid flow regime in the mine environment and numerical modelling of the deformation and fluid flow regime to replicate the ore positions
- Application of this knowledge in the regional context to focus exploration in the most prospective areas
- Successful discovery of new gold mineralisation in the company's exploration leases.

## Project goals and deliverables

The T1 project is a predictive mineral discovery Cooperative Research Centre (pmd\*CRIC) collaborative project between University of Melbourne, CSIRO Exploration and Mining and MPI Mines (later Leviathan Resources Limited). The principal goal of the T1 project was to integrate field, geochronological and geophysical data in a collaborative effort, to develop 3 and 4-dimensional geological models of the crust at a range of scales to predict the location of new mineral deposits in western Victoria.

In order to achieve the primary pmd\*CRIC project goal, four key deliverables were designed:

- Establish links between structural studies of crustal rock associations to subsurface geophysical data. In particular how aeromagnetic/gravity anomalies were related to mineralisation processes by empirical and theoretical rock-magnetic (magnetic petrophysics) studies of rocks from mineralised versus nonmineralised;
- Petrophysics interpretation of magnetics and gravity data:
- Develop 3-dimensional predictive models of the crust on three scales:
  - (1) Drillcore scale petrophysics - Magnetic susceptibility, density, electrical properties, radiometrics, seismic properties.
  - (2) Prospect scale trials - electrical methods and detailed gravity.
  - (3) Prospect and larger scale modelling - of magnetics and gravity.
  - (4) Larger scale - "Worming" images of gravity/magnetic data sets, teleseismic tomography and seismic interpretation and modelling of deeper crustal structure in western Victoria (from Delamarian Orogen to Avoca Fault).
- Fluid flow modelling of hydrothermal processes to predict key fluid flow sites at the time of mineralisation on three scales:
  - (1) Prospect scale– 3-dimensional.
  - (2) Belt scale – 2- and 3-dimensional.
  - (3) Regional scale – 2- and 3-dimensional

## Project achievements

The pmd\*<sup>CRC</sup> project operated for a little over three years, and in this time interacted with the H4 pmd\*<sup>CRC</sup> History project to establish absolute timing relationships in the Stawell Zone. The T1 research project was funded by MPI Mines Limited and by the pmd\*<sup>CRC</sup> as a “Flagship Project” and this final report brings together a vast wealth of new knowledge, information and data, and is accompanied by a DVD that presents the 3D- Models developed for western Victoria. Results have been collated and presented in this volume as a series of papers that will be supplemented with a further series of papers from a complimentary ARC-Linkage Project; together these papers will be published as a thematic issue of the Australian Journal of Earth Sciences in 2006.

The report is structured around the application of multi-disciplinary predictive techniques that have resulted in the discovery of at least two new mineralised systems under barren cover, at Wildwood and Kewell. Chapter 1 sets the geophysical scene that has been used in interpreting the geology and building the 3D models. Chapter 2 summarises some of the petrophysical results and implications for interpretation of aeromagnetic anomalies. Chapter 3 shows that the most important control on the formation of the Stawell ore-bodies is the geometry and properties of the Magdala Basalt dome and its effect on the localisation of hydrothermal fluid flow during the ore forming hydrothermal event. Chapter 4 elaborates on the workflow and correlation of modelling results with real geometries that have been used to construct the 3D models both on a mine scale and regionally. Chapter 5 describes a crustal-scale model for western Victoria. Chapter 6 summarises structural mapping and the use of 2.75 forward modelling to constrain the 3D geometry of regionally significant faults. The T1 project was a learning exercise for all involved and as the current mine at Stawell provided the best geological constraints on the origin of the gold shoots, this was selected as the first test area and will be described in detail in Chapters 3 and 4. Where “Dome scale” modelling was used to simulate zones of enhanced fluid flow that matches the overall distribution of the Magdala and Golden Gift ore shoots (Figure 1).

It was recognised by the Leviathan Resources exploration group that successful exploration for other buried domes within the Stawell Corridor would require a well researched predictive model. The first stage in the development of regional predictive models for new ore systems in western Victoria was the characterisation of the key geological elements of the Stawell ore system. Additional geophysical data was collected over key prospects. In particular, detailed gravity data proved an effective filter for basalt domes versus other magnetic features. Inversion modelling of gravity and magnetics assisted construction of 3-dimensional basalt dome models. 3D models were then constructed for numerical simulation modelling of fluid flow and dilation at the time of mineralisation on surfaces that were restored to geometries that existed prior to any post-mineralisation faulting (Chapters 3 and 4). Stress orientations and rock properties were as determined through previous and concurrent ARC funded research. The combined results of ENE-WSW + E-W compression, based on Stawell structural history (Miller & Wilson 2002; 2004) simulated high fluid flow on the upper shoulders of the domes, particularly the shallow plunging WSW flank and steeply plunging ENE flank (e.g. Figure 2). Predicted dilation was concentrated on the upper shoulders of the dome. The intersection of these areas of high fluid flow and dilation with the eroded Murray Basin interface is a 1.6km long zone on the SW flank and a smaller zone on the northern end of the Kewell basalt (Figure 2). These zones are coincident with elevated aircore geochemistry.

The results of the geochemical characterization (through an ARC project) and fluid flow/dilation modelling were combined to produce specific diamond drilling targets. The first target selected for drilling was the southern end of the Kewell dome on section 5967600mN (Figure 3). Drill hole KD003 intersected a brecciated quartz lode followed by a thick section of mineralised volcanogenics including a basalt bound “Waterloo” with visible gold, on a shallow west dipping basalt contact. Intersections included 4.2m @ 3.46 g Au/t from the hangingwall lode and 4.1m @ 12.6 g Au/t from the Waterloo (Figure 3). Subsequent drilling results included 6.25m @ 10.2 g Au/t in KD005 (Figure 3).

Similar modelling and targeting has also been undertaken at the Wildwood prospect with initial results including an intersections in WRC076 of 10m @ 12.7g Au/t. Further drilling is in progress and time will tell whether Kewell and Wildwood are significant new discoveries. However, these are example of a step

change in an exploration strategy with a significant reduction in time and cost to discovery through a multidisciplinary approach to predictive mineral discovery.

The question of the crustal architecture and whether there are deep penetrating faults along which mineralised fluids could enter the western Victorian crust has been tackled via a 3D geological model (Chapter 5). Embedded within this are existing gold deposits, prospects and targets. Through a combination of geophysical forward modelling (as in Chapter 6), numerical simulation and existing seismic data, the 3D model was developed to inform the explorationist on prioritising resource opportunities in the region. The model largely affirms the major boundaries, as determined by the GSV mapping, some changes in fault positions are warranted (e.g. the Moyston Fault, south of Stawell) and there are changes in emphasis regarding the relative dominance of some structures – for example, the Pleasant Creek Fault is modelled as a major break that significantly impacts on the 3D architecture as much as, if not more than, the Moyston Fault.

The Coongee Fault, being a locus for gold mineralisation, represents a major steep west-dipping boundary, separating low grade from substantially high grade metamorphic rocks to the west. In the model, it appears to have formed as a backthrust to a major ramp developed in the basal detachment geometry. It has undergone later strike slip sinistral reactivation.

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