Oct-Dec 2006

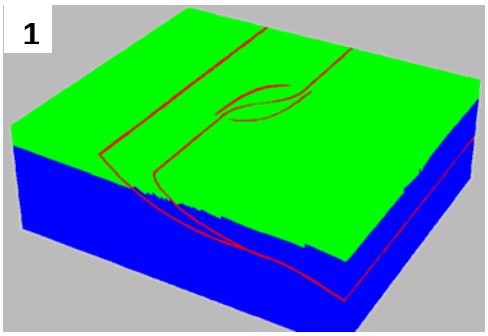
Y4 Project Quarterly Report

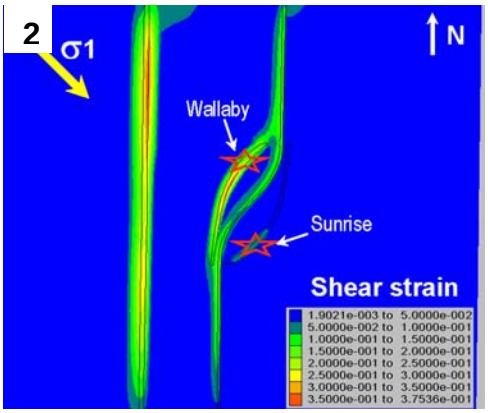
predictive mineral discovery CRC

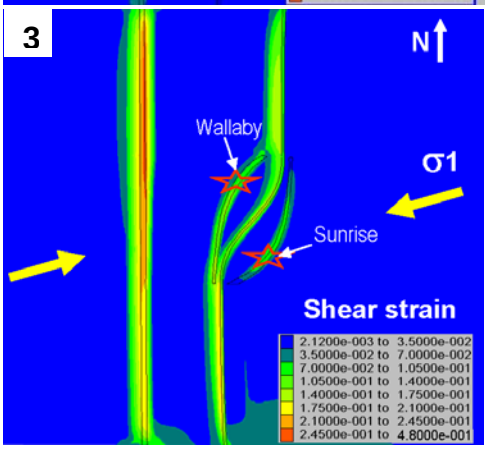
Highlights:

- Numerical simulations of Laverton
- Sunrise Dam Structural Report
- New Sm-Nd map better defines 'terranes'
- Metamorphic scenarios
- Embedded Researcher and Student News
- Structural posters for Wiluna
- Fascinating Geodynamic synthesis chart
- New look at the crust: MT inversion
- Reactive transport code – linking fluid flow and chemistry
- Pipe-like fluid pathways

Modelling the sinistral slip system of Sunrise Dam and Wallaby



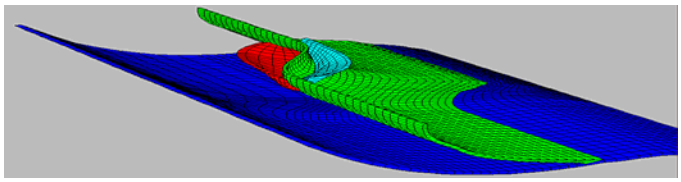




Recent modelling by Yanhua Zhang (CSIRO) has focused on the Laverton region to test the concept of the "Painted Faults" targets (Miller 2006; Henson & Miller 2006). The model architecture is a positive-flower structure (Henson et al. 2006) comprising a detachment fault, a central thrust, and two splay faults (Fig. 1). Preliminary findings include:

- NW-SE shortening led to sinistral shearing in the fault system (Fig. 2). Relatively high shear strain and dilation (positive volumetric strain) developed in the western fault splay (ie Wallaby). Minimal shear and dilation occurred in the SE (ie Sunrise).
- ENE-WSW shortening (Fig. 3) resolved dextral shear in the fault system. The eastern fault splay (Sunrise) under this stress field showed more shear strain and dilation enhancement in comparison with that under the sinistral shearing scenario. The western fault splay (Wallaby position) now showed weakened shear and dilation localization in comparison with the sinistral shearing case.
- The preliminary results support the concept that the main fault at Wallaby was more favourably oriented for mineralisation under sinistral shearing, whereas the main fault at Sunrise was more favourably oriented for mineralisation in the dextral shearing event. This is also consistent with the observation that the Wallaby major gold phase was associated with sinistral shearing but the Sunrise major gold phase was associated with dextral shearing (see Miller and Nugus on Twiki).
- More simulations with differing stress orientations will be conducted through the next quarter.

Generic architecture simulating the restraining bend system at Laverton



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PROJECT TEAM

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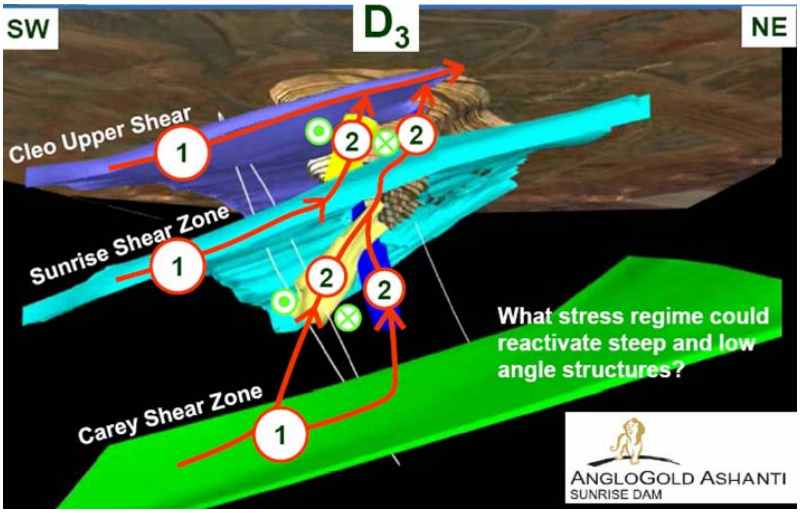
Sunrise Dam report and final presentation to site

The SRD report is posted on Twiki and the final presentation of this work by John Miller (CET-UWA) and Mike Nugus (AGA) to sponsors on site this quarter. A few of the findings in this comprehensive study are:

- Two major stress switches are inferred to have occurred around the same stress axes (i.e. not via progressive rotation).
- Linked to waning of the D2 regional orogenic event (possible subduction zone roll back = D3) and then recommencement (=D4)
- Other changes linked to change in stress shape ratio or via switching between σ2 and σ3 when they were close in magnitude
- Stress switches are inferred to have allowed the system to access different fluid reservoirs, and also changed the fluid pathways, producing the observed sudden changes in alteration e.g., arsenic vs. base metals.



View NW of Sunrise Dam architecture at D3 time. Low angle shears fail first (1), followed by steep structures (2) fail at strike changes. The opposite occurs during D4. See report for more details

Deliverables next quarter

- Anthony Morey PhD
- Revised magneto-telluric (MT) image and its interpretation/integration with the EGF01 seismic line transect and receiver function data
- Revised gravity inversion at 2 km cell size for all of the Eastern Yilgarn (extending and improving Y2 work)
- Numerical simulations testing the Laverton restraining bend architecture
- Metamorphic report # 4
- Site visits (in addition to Embedded Researcher studies on site)
- Sm-Nd dates on metamorphic garnet
- Reports on new detrital-zircon age data for Late Basins and Black Flags, and whole-rock geochemistry and logging at St Ives and Agnew

DID YOU KNOW?

The Eastern Yilgarn is not all low to medium grade metamorphic rocks. We have described static metamorphosed two-pyroxene mafic granulite at three localities in the southern Duketon Domain (E of Laverton).

Embedded Researcher (ER) News

Tony Roache at St Ives:

- Ongoing work on the Greater Revenge Area Gocad model.
- Preparation of talks for the Gold Fields geological conference and the Y4 pdt meeting.
- Organisation of an alteration mapping workshop at St Ives.
- Supervision of students
- Started the acquisition of more spectra using the HyChips/Logger system.
- Processed EOH air-core spectra.

Achievements

- Good response to the recommencement of the HyChips/Logger system at St Ives by project geologists. The results from the first phase of Gocad modelling have demonstrated the need for spectra for routine geological interpretation.
- The latest outcomes from the M377 research, including spectra modelling, 'minmoles', and Leviathan targeting, has renewed enthusiasm in the project.

Carl Young at KB:

- Processed and corrected errors in the Barrick Kanowna drillhole database. This resulted in changes to the multi-element, multi-spectra and isotope sample locations.
- Modified and collated additional data into the Gocad model.
- Continued processing and interpreting the hychipper results; the results have been synthesised into an internal report (incomplete).
- Conducted a couple of days of geochemical training.
- Attended (and presented at) the PDT and the Barrick Exploration meetings in Perth in November.

Mark Pirlo at Granny Smith:

- Interpretation of existing S and C-O isotope data and 3D Leapfrog model of Wallaby to determine sample strategy for additional sampling
- Sampling for S and C-O isotopes across the Wallaby pipe
- Logging of drill core to determine key alteration across the Wallaby pipe to complement isotope sampling program
- Modelling of alteration and isotope data in 3D to identify fluid chemistry in specific conduits
- Sampling for additional spectral analysis
- Examination of thin sections of key alteration samples and selection for follow-up microprobe analysis.

Student News

Joanna Hodge (UWA):

- submitted NC paper to Econ Geol
- completed LA in situ sulphur isotope work on Golden Mile and St Ives samples at CSL at UTas
- completed LA-ICP-MS analysis on pyrite and magnetite from GM, St Ives and New Cel at CODES, UTas

Anthony Morey (UM):

- Completed final chapter, which incorporates regional geophysical worm data and conceptual models of regional architecture of the Bardoc Tectonic Zone. Through comparisons with the Boulder-Lefroy Shear Zone, this chapter identifies the regional characteristics of a shear system that would favour the formation of world-class orogenic deposits.
- Anthony Morey shall hand his thesis in during the second week of January 2007.

Nick Williams (UBC):

- Completed formal PhD research proposal and comprehensive oral examination requirements
- Thesis tentatively titled: "Integrating geology and geophysics through 3D inversions at local and regional scales: The Perseverance nickel deposit and Agnew-Wiluna greenstone belt"
- Thesis research will consist of four modules: 1) Understanding physical properties of rocks in and around the Agnew-Wiluna greenstone belt, and in particular the Perseverance Ni-sulphide deposit; 2) Incorporating geological constraints into potential field inversions to improve their reliability and predictive capabilities in the subsurface; 3) Developing methods to predict geology, particularly rock types and mineralogy, from physical property models recovered using inversion; 4) Building simple 3D models of subsurface geology at regional, district, and local scales based on inversion modelling.
- Modules 1 and 3 are at an advanced stage and continuing research will focus on modules 2 and 4.

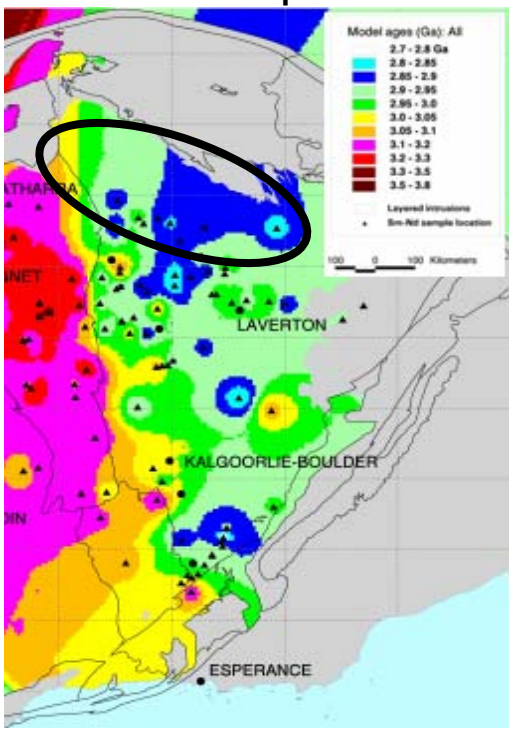
Y4 Project Development Team (PDT) Meeting and workshop

A successful pdt meeting was held on the 21-22 November at the ARRC Building in Perth. The first day was delivery-focussed with presentations from the Embedded Researchers and students, as well as updates on Northern Yilgarn structural correlations, metamorphism, time-space analysis, numerical simulations. The morning of day two focussed on Sunrise Dam with both delivery from Y4 and G15 (the one-on-one project run out of the mine). The afternoon of day two was a workshop on Yilgarn geodynamics and the emphasis very much on discussion rather than delivery. Copies of the talks and agenda are on https://pmd-twiki.arrc.csiro.au/twiki/bin/view/Pmdcrc/YilgarnPdtNov06

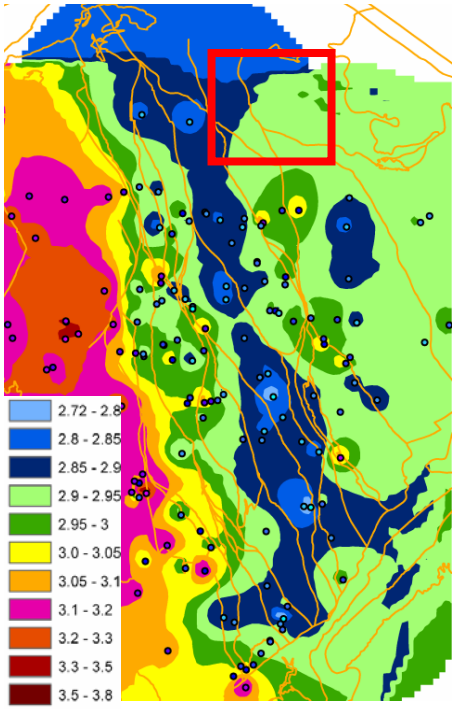
New Sm-Nd map of the Yilgarn Craton highlights favourable country(?) undercover

The Y4 project acquired 12 new Sm-Nd data points from granites to infill the excellent map from Dave Champion and Kevin Cassidy in key northern areas (*ringed area in lower left picture*). We were hoping to refine the boundary in the isotopes and test whether the undercover extension of Laverton-Duketon has a favourable mantle separation age of ~2.9 Ga or the less favourable younger age (*red square on revised map*). Good news – it is, and the project plans to build a 3D map over this undercover area as part of its 'targeting' process. The position of the Ida fault (as determined by the isotopes) is now more precisely defined in the north near Wiluna. For a discussion and copies of the map go to:
https://pmd-twiki.arrc.csiro.au/twiki/bin/view/Pmdcrc/ProjectY4

Old map



Revised map



DID YOU KNOW?

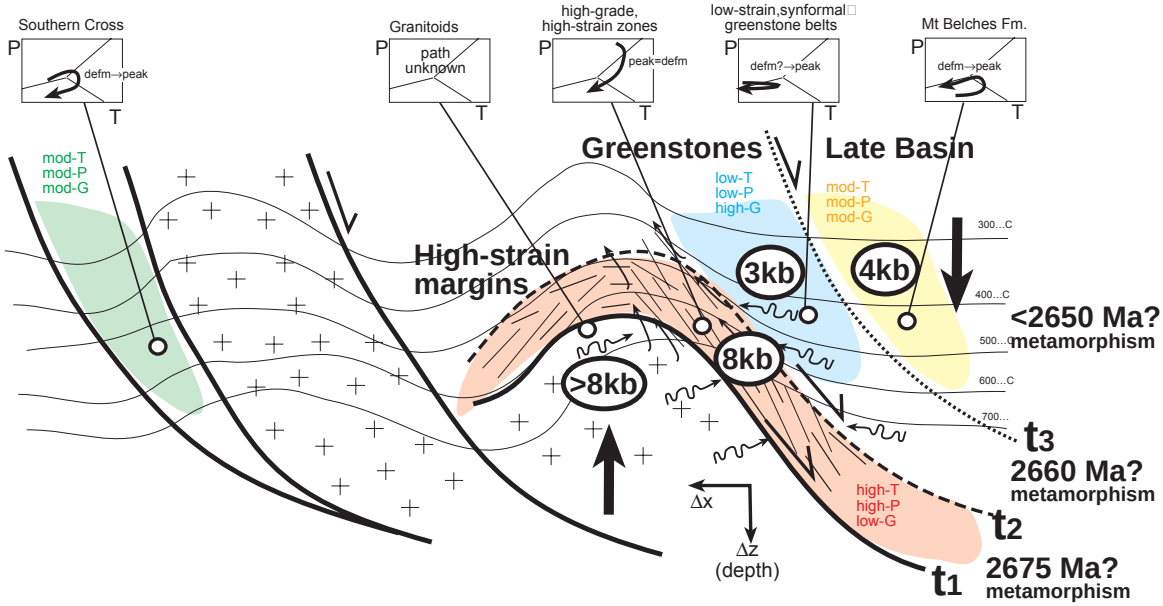
The Preliminary Sequence of Mineral Growth (SMG) indicate a wide variety of P-T paths of evolution in different parts of EYC: (1) clockwise - decompressional, (2) anticlockwise - up-P, (3) tight heating and cooling paths, (4) and two stage metamorphic histories (ie 2nd metamorphic event reworking earlier – typically higher grade metamorphic event)

Metamorphic Report number 3 delivered

As usual, there is a wealth of 'gems' in Ben Goscombe's (Adelaide Uni) metamorphic report. One of the highlights is a proposed scenario to explain a number of fundamental observations:

- Low-G (cool thermal regime) high-P domains juxtaposed against shallow high-G (hot thermal regime).
- Metamorphism of deeper rocks apparently dominated by advection over conduction.
- Strong correlation between high strain and low-G, high-P rocks.
- Apparent advective exhumation of high-P area due to either
- Focused erosion, or (b) extension.

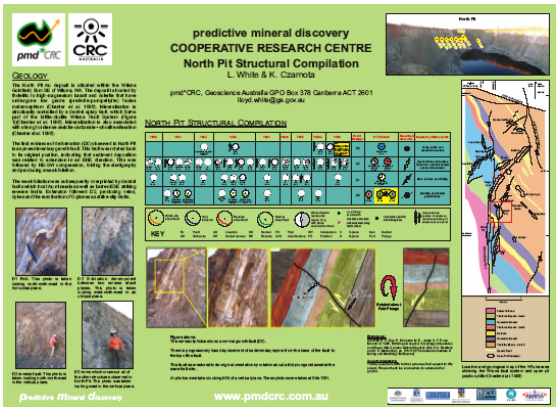
Copies may be downloaded from: https://pmd-twiki.arrc.csiro.au/twiki/bin/view/Pmdcrc/ProjectY4#Metamorphism_Reports.



Revised schematic generalized relationships between the domains of different metamorphic style (thermal regime) in the East Yilgarn Craton.

Wiluna structure – posters available

Karol Czarnota and Lloyd White (GA) have completed 6 posters from their structural work around Wiluna. Structural history of Wiluna region is very similar to Kalgoorlie with upright NNW trending upright folding followed by NNW trending ductile sinistral shearing which is cut by brittle dextral faults.

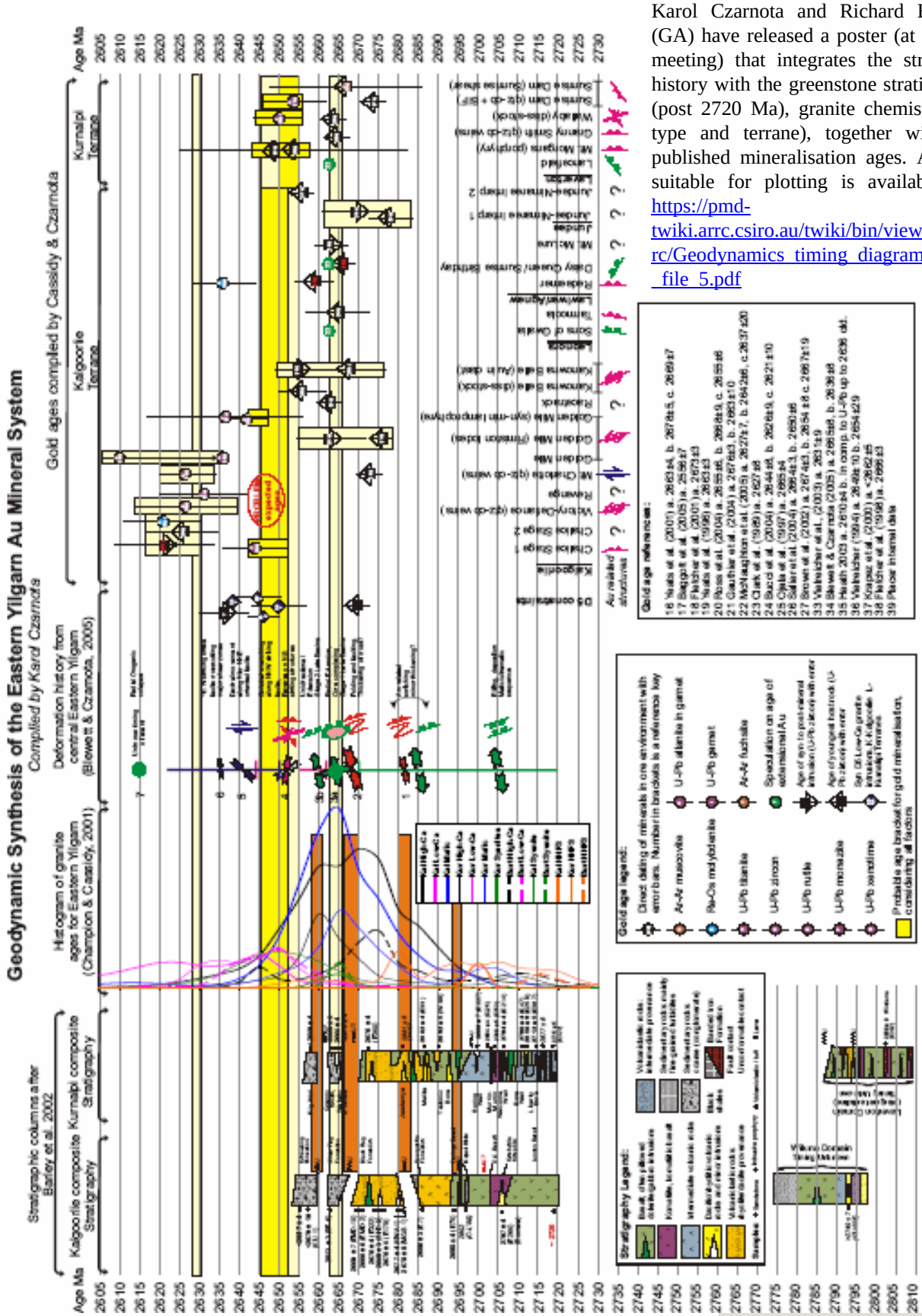


North Pit Wiluna poster

A **key finding** from this work is that the sinistral shear (cf. 'D3' deformation at Wallaby and SRD and also at St Ives and KB) was the result of regional (far-field) E-W contraction. No plate-scale rotation of the stress field is required, and at ~2650 Ma localised (but regionally distributed) NW-SE contraction occurred across restraining bends and step overs of sinistral faults (cf modelling Laverton architecture).

Go to Y4 Twiki page to download the 6 posters: https://pmd-Twiki.arrc.csiro.au/twiki/bin/view/Pmdcrc/ProjectY4#Structural_geology_of_the_Wiluna

Geodynamic synthesis poster released



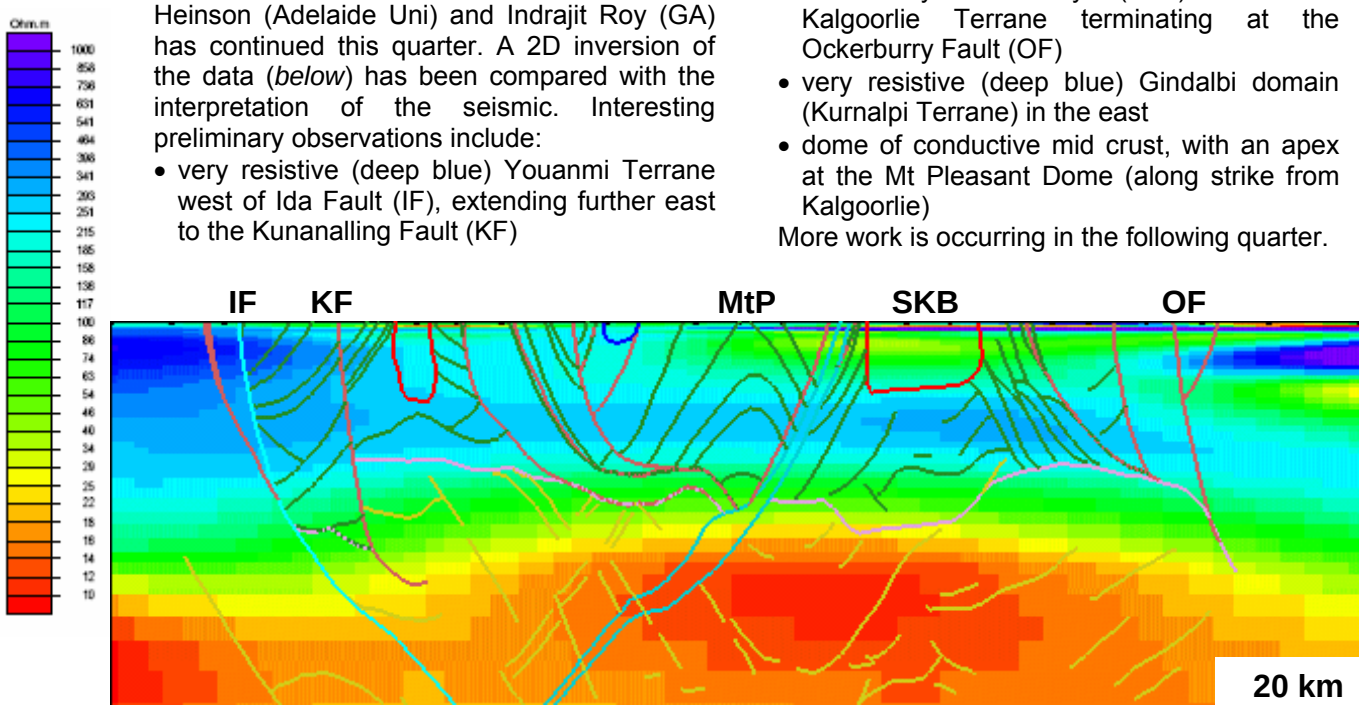
Karol Czarnota and Richard Blewett (GA) have released a poster (at the pdt meeting) that integrates the structural history with the greenstone stratigraphy (post 2720 Ma), granite chemistry (by type and terrane), together with the published mineralisation ages. A copy suitable for plotting is available on: https://pmd-twiki.arrc.csiro.au/twiki/bin/view/Pmdcrc/Geodynamics_timing_diagram_open_file_5.pdf

A new cross section of the Yilgarn's crust: MT results

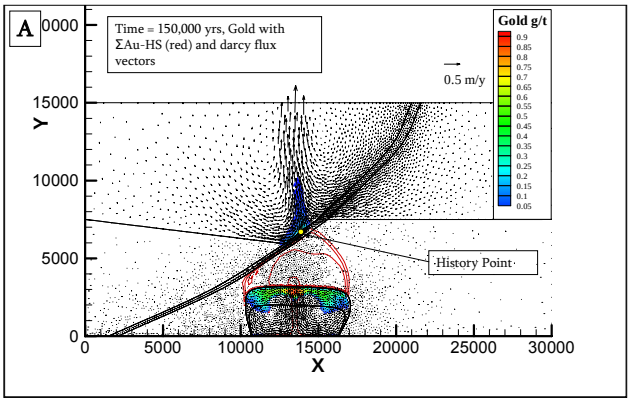
The magneto-telluric processing by Graham Heinson (Adelaide Uni) and Indrajit Roy (GA) has continued this quarter. A 2D inversion of the data (*below*) has been compared with the interpretation of the seismic. Interesting preliminary observations include:

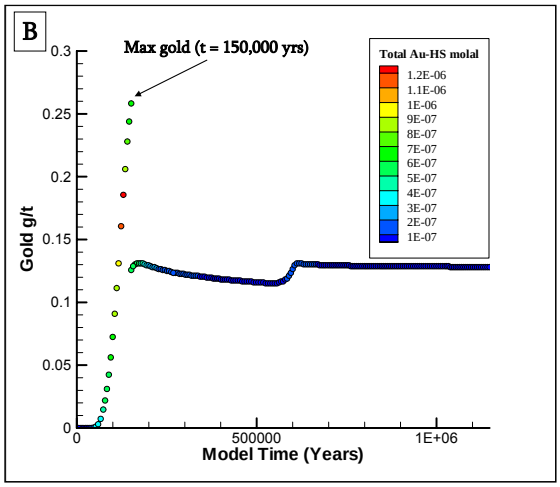
- very resistive (deep blue) Youanmi Terrane west of Ida Fault (IF), extending further east to the Kunanalling Fault (KF)
- moderately resistive layer (blue) beneath the Kalgoorlie Terrane terminating at the Ockerburry Fault (OF)
- very resistive (deep blue) Gindalbi domain (Kurnalpi Terrane) in the east
- dome of conductive mid crust, with an apex at the Mt Pleasant Dome (along strike from Kalgoorlie)

More work is occurring in the following quarter.



pmdPyRT coupled modelling: update on Yilgarn tests



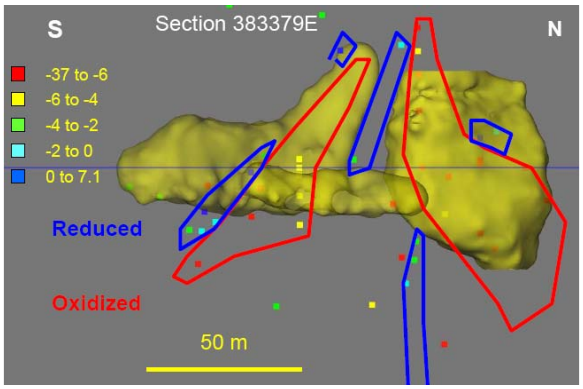


James Cleverley (CSIRO) has refined the listric Fault Granite model (LFG) is testing the latest version of pmdPyRT to explore complex coupled simulations including chemistry.

This model (Fig A) uses geological units (greenstone, felsic basement and granite) with the top fixed to 5 MPa (500m) and 40ºC, with an initial 35oC/km thermal gradient. The granite is initialised at 600ºC and has an elevated heatflux (100 mw/m2) for 150,000 years. After this the basal heat flux is uniform across the bottom of the model (85 mW/m2).

Gold is populated in the granite fluid at the start of the model at below saturation (~2 ppm), and is precipitated at the top of the granite (effect of decreasing temperature and low permeable host rocks preventing transport) and also in a zone in the greenstones above (Fig. A). Figure B shows the history (gold versus time in years) for a point in this greenstone gold zone (yellow dot on Fig. A) with the points coloured by total Au-HS concentration. The bulk of the gold is actively precipitated during the active granite cooling stage, with a small amount later. This is related to the flux of Au-HS, and likely desulphidation of this fluid in the greenstones.

3D modelling stopes and S isotopes map pipe-like pathways



Peter Neumayr (UWA-CET), John Walshe (CSIRO) and Klaus Petersen (UWA) together with embedded researchers Tony Roache, Mark Pirlo and Carl Young have refined the understanding of fluid flow paths, fluid chemistry and relationship to gold deposition at St. Ives, KB and Wallaby. In particular, extensive sulphur isotope data from Victory Defiance (St Ives) allowed detailed interpretation of fluid flow paths, temporary seals in the system and prediction of gold depositional sites. Sampling was greatly assisted by a detailed 3D Leapfrog model (*left*). The new data resulted in detailed prediction of targets underneath Victory Defiance.
For more details see presentations at the PDT (on Twiki and DVD).

N-S section through Victory Defiance showing the distribution of S isotope values, the pipe-like shape of mine stopes (yellow surface) and the interpreted fluid composition (red and yellow lines) based on S isotope compositions and alteration mineralogy. The S isotopes are best interpreted with an oxidized fluid flow along moderately south and north dipping fluid conduits and a steep reduced fluid flow.

List of project events for the quarter

Project meetings and field activities

Name	*Date*	*Venue*	*Number of Researchers*	*Number of sponsors*
Fieldwork – sampling and mapping (RS)	2-12/10/06	St Ives	1	
Fieldwork – sampling and mapping (RS)	12-19/10/06	Agnew	1	
Fieldwork JW, PN, TR at St. Ives including workshop and attendance of the GoldFields conference	13-17/11/06	St. Ives Kalgoorlie	3	10
DC presented two themes at St Ives on “Granites of the Yilgarn” and “how to deal with porphyries”	14/11/06	St Ives	1	10
Y4 annual PDT meeting	21-22/11/06	Perth	15	~50
RS Fieldwork	11-13/12/06	St Ives	1	
JM site presentation to Sunrise Dam	19/12/06	Sunrise Dam	1	5

Workshops

Name	Date	Venue	Number of researchers	Number of sponsors
RS workshop ”Distinguishing between volcanic and sedimentary breccias”	11/10/06	St Ives	1	7
RS workshop “Lithological controls on the distribution of gold at the Agnew Gold Mine”	18/10/06	Agnew	1	5
WS by JW, PN, TR, C.Y., Scott Halley	15/11/06	St. Ives	4	10
Yilgarn Geodynamics	22/11/06	Perth	15	~50

Conferences/Symposia

Name	Date	Venue	Number of researchers	Number of sponsors
Goldfields Science conference (PN, JW, DC, RB), with presentations by DC and RB	16-17/11/06	Kalgoorlie	4	~40
Presentation by PN to CET sponsors about project activities	6/12/06	UWA	1	30

Shortcourses

Name	Date	Venue	Number of researchers	Number of sponsors
Peter Neumayr, Klaus Petersen and John Walshe continue to provide on-site training and development for sponsors	various	On site: St Ives, Wallaby	variable	variable