Jan-March 2007

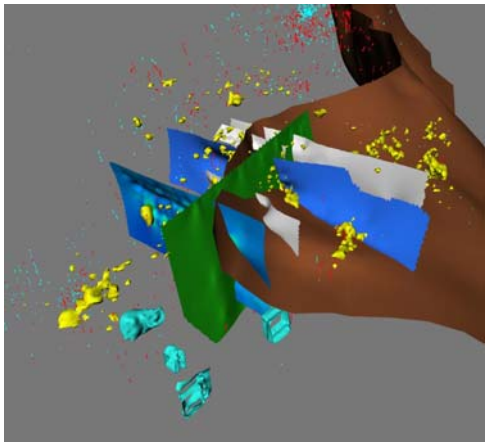
Y4 Project Quarterly Report

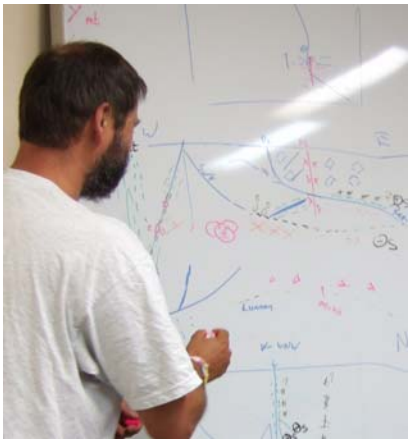
predictive mineral discovery CRC

Highlights:

- St Ives targets
- St Ives fluids
- St Ives structures
- Sunrise Dam and extending the Carey Shear
- Regional metamorphic update
- Embedded Researcher and Student News
- New look at the crust: MT inversions
- Modelling Laverton σ1

Targeting @ St Ives: an example of sponsor-researcher collaboration





The Y4 Perth team has developed the chemical and structural architecture of the St Ives gold camp in 3D space allowing assessment of chemical controls on mineralisation and prediction of the location of further gold lodes (especially in the Greater Victory area). The Y4 team, together with St Ives geologists, used state-of-the-art 3D viewing at CSIRO to interrogate the models and generate a number of new 3D drill targets. The presentation facilitated the translation of the targets into the underground mining world.

Conceptual drill targets were identified using the assumption that evidence for both oxidized and reduced fluids has to be in the target. This assumption is based on observations that nearly all ore bodies at St Ives show this relationship. Using intersections of oxidised and reduced structures guided us to the targets.

The model predicted steeply-dipping WNW-trending structures with a reduced fluid signal and also NNW-trending steep structures with an oxidised fluid signal. Hydrothermal magnetite distribution in 3D was used to constrain the oxidised structures and porphyry intrusions and gold trends were initially used to constrain the reduced structures. Once located in 3D using the extensive drill log database on site, hydrothermal alteration assemblages were "ground proofed" in drill core. The characteristic alteration assemblage in the reduced structures is amphibole-biotite±pyrrhotite. The model was also used to locate suitable drill core for extensive stable isotope sampling to constrain redox state of the hydrothermal fluids. The stable isotope analyses confirmed the redox state of the fluids as determined with the mineral assemblages.

Feedback from sponsors Goldfields St Ives has been very positive: “the meeting was fantastic; it’s been very hard to bridge the gap between what you (researchers) are seeing and interpreting, and transferring that knowledge to the mine geologists and exploration geologists. (Janet Tunjic – Senior Project Geologist)”.

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Klaus Petersen,
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Mark Kendrick,
Mark Pirlo,
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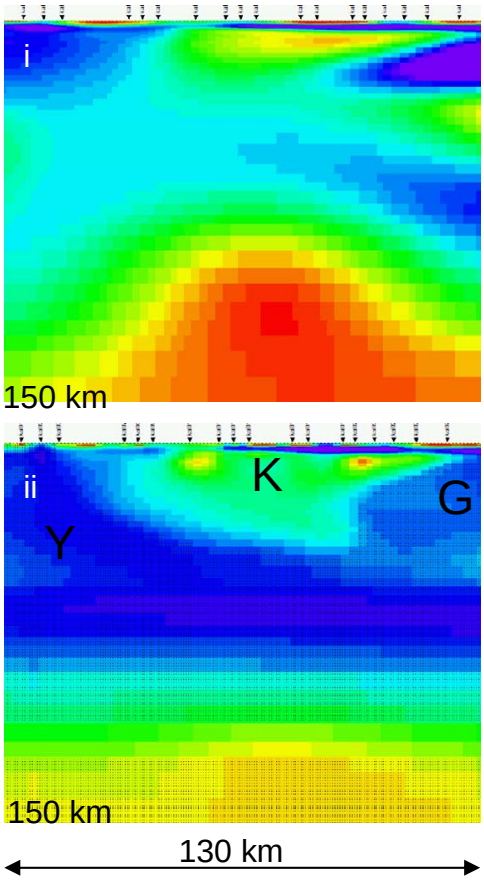
Paul Henson,
Peter Neumayr,
Roland Maas,
Rick Squire,
Terry Brennan,
Tony Roache,
Yanhua Zhang.

New detrital-zircon age dating of basins

Rick Squire (Uni Melb) has analysed ~950 detrital zircons from six samples in the St Ives, Kundana, Agnew and Granny Smith regions were analysed using the LA-ICP-MS. Confirmation SHRIMP analyses of key populations will be undertaken next quarter, but preliminary results are presented here.

Single age populations of 2678±5 Ma and 2656±10 Ma were found for samples from Argo in the St Ives region and the Ballarat Turbidite east of the Kanowna Belle mine, respectively. A sandstone from Ora Banda also had a single population at 2657±12 Ma, but contained a single old grain at ~3327 Ma. The Potaroo Turbidite from the Granny Smith region has a broad spread of age with a dominant age at ~2719±5 Ma and minor groups at ~2762 Ma and ~2934 Ma. At Agnew, a sample of Jones Creek Formation on the northeastern side of the Agnew Anticline near Viviens contained two populations at 2785±9 Ma and 2683±7 Ma. A sample of the Scotty Creek Formation on the western side of the Agnew Anticline near Redeemer contained a broad spread between 2665 Ma and 2777 Ma. It is interesting to note that the samples from Kanowna Belle and Ora Banda are strikingly similar, despite being in different domains, and the samples from Agnew that are inferred to be roughly along strike from each other have remarkably different provenance. These issues are being investigated.
For further information contact Rick.Squire@sci.monash.edu.au

Modelling the electrical properties of the Yilgarn lithosphere: an update of the MT results



Modelling of the magneto-telluric (MT) data (i - unconstrained inversion) has shown that the well-endowed Kalgoorlie Terrane (K) is an anomalously conductive (warm colours) crustal section (ii). This unconstrained 2D inversion shows that the crust to the east (Gindalbi - G) and west (Southern Cross or Youanmi - Y) are characteristically resistive. The upper mantle is conductive, 'pointing' to Kalgoorlie above.

A series of inversions (14) with varying constraints were run. The preferred inversion is shown (ii). This inversion shows that the Kalgoorlie Terrane is a conductive region between a Y-shaped resistive crustal section. The mantle dome is removed, but the model is to fit a more conductive region below K.

The inversion software applies 'soft' constraints where the model space is explored and constraints rejected if the data contradict the constraints.

The Kalgoorlie region is up to 1000x more conductive than the rest of the crust around it. This could be explained by the presence of:

- free fluids;
- graphite; and/or
- sulphides.

An implication of these results is that "giant systems" can be mapped as anomalously conductive sections (*cf.* Olympic Dam). For more information contact richard.blewett@ga.gov.au

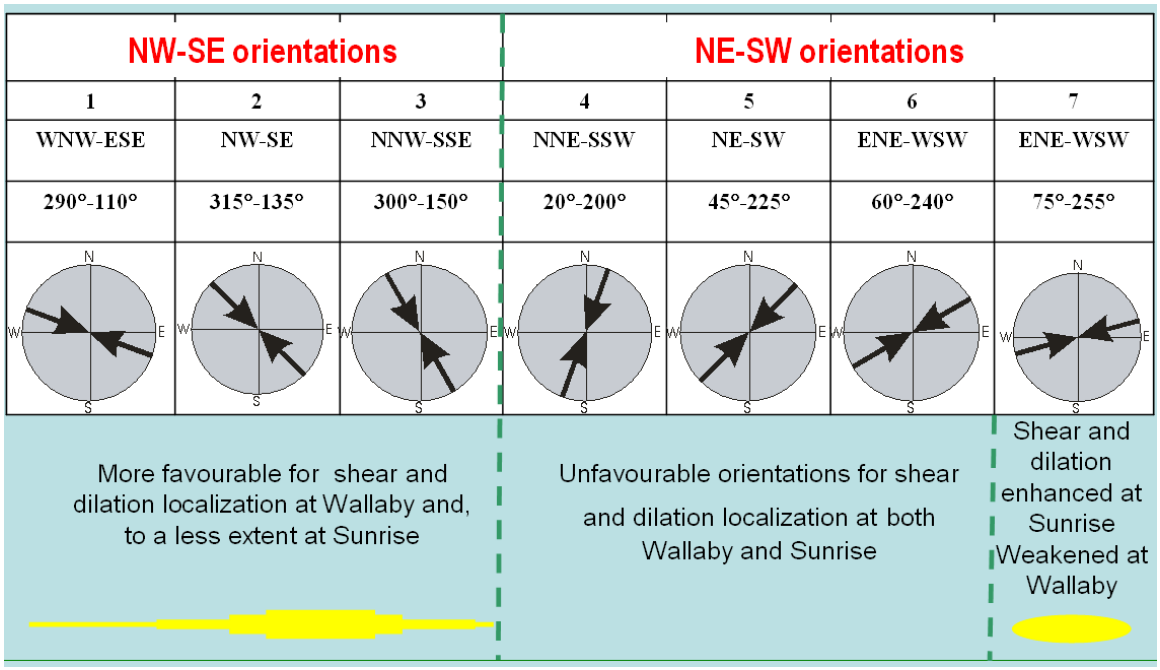
What is the best direction to crunch a deposit at Laverton?

Yanhua Zhang (CSIRO) has continued with the Laverton region fluid-flow modelling to test the effects of a range of shortening (far-field maximum principal stress) orientations have been simulated for the simplified fault structures of the Laverton region (see below). The results show:

1) Shortening from NW-SE to NNW-SSE seems to be clearly favourable for structural reactivation (shear & dilation) of the Wallaby system and mineralization
2) Sunrise Dam area has some shear localisation and dilation under such conditions but by a much lesser amount
3) Shortening orientations around NE-SW are unfavourable for shear and dilation localization at both the Wallaby and Sunrise fault systems
4) An ENE-WSW shortening orientation (75 to 255º) led to enhanced shear and dilation localization at Sunrise, but less at Wallaby.

These results are consistent with the regional stress field calculations of Karol Czarnota and Richard Blewett, the detailed mine studies by John Miller and also 3D architecture predictions of Paul Henson.

For more information contact yanhua.zhang@csiro.au



Testing contractional directions and fluid flow at Laverton: NW-SE and ENE-WSW orientations are most favourable

Student News

Joanna Hodge (UWA):

- Attended far-field alteration around giant ore deposits short course and Roundup conference in Vancouver
- Finalizing thesis
- Submitted samples to GA for zircon dating

Anthony Morey (UM):

- Submitted thesis and posted to Twiki 16 Jan.

Nick Williams (UBC):

- Presented poster on the physical property results at the Mineral Exploration Roundup in Vancouver
- The poster, my PhD proposal, assorted physical property data, plots, and interpretations, as well as a more comprehensive report are provided on ftp://ftp.eos.ubc.ca/pub/nwilliams/Package4BHPB.zip.
- Attended PDAC in Toronto and presented general paper on inversion methodology.

Elena Belyavtseva (CET)

- Joined the project in April and will be focussing on prospectivity analysis of the Yilgarn using Y2-Y4 data.

More on St Ives fluids .....

The fluid team of Peter Neumayr, John Walshe and Klaus Petersen together with embedded researchers Tony Roache, Mark Pirlo and Carl Young have refined the understanding of fluid flow pathways, fluid chemistry and their relationship to gold deposition at St Ives, Kanowna Belle and Wallaby.

John Miller confirmed the existence of WNW-trending steep structures, defined in 3D space in fluid/alteration data at St Ives, and that they were active during, and possibly controlled location of, gold mineralisation. This is an excellent example of where predictions using a 3D model have been “ground truthed”. This methodology can now extended for other targeting exercises.

A new batch of C-O and S isotopes is being used to refine the Victory 3D alteration model. A possible vertical zonation under Victory with progressively more oxidized alteration at greater depth (i.e., closer to source). This interpretation is consistent with models of a core of felsic intrusions in the dome under Victory and that oxidised magmatic vapours are one of the fluids responsible for gold mineralisation. The S isotopes also indicate that additional temporary fluid seals existed under Victory-Defiance. These seals are typically marked by interflow sedimentary layers.

Klaus Petersen (CET-UWA) analysed a total of 17 fluid inclusions chips mainly from the Conqueror and Revenge deposits at the Leeds University facility (UK). The methodology used was that by Bruce Yardley and Dave Banks, with a focus on all the alteration types identified during the detailed petrographic and fluid inclusion analysis work to date. The following elements were analysed (Na, K, Ca, Mn, Fe, Cu, Zn, Sr, Ag, Pb, Ta, Au, and Sr). Both altered and unaltered quartz porphyroblasts of several porphyries had additional Rb and Cs analysed.

Processing these data is underway and we expect to be able to characterise the different fluids and/or source of fluid(s) for some of the alteration phases. Preliminary assessment of the unprocessed data indicates that fluids with significantly different chemical ratios exist. Klaus hopes to test the relationships between the porphyry-related fluids and the known alteration stages.

Leeds ICPMS facility

Unfortunately no significant gold was detected in the inclusions, however the epidote-magnetite alteration stage provided some good numbers on silver.

For further information contact kjpeters@segs.uwa.edu.au

Mark Kendrick analysed halogens from an albite sample (LD7113A/135.50m) from St Ives. Preliminary results reveal an $^{40}Ar/^{36}Ar$ ratio of ~16,000 and magmatic-like Br/Cl and I/Cl ratios that are compatible with deep fluids from either a magmatic or metamorphic source. Noble gases including Ar, Kr, Xe, He and Ne will be analysed this quarter to better define the fluid sources.
For further information contact Mark.Kendrick@unimelb.edu.au

DID YOU KNOW?

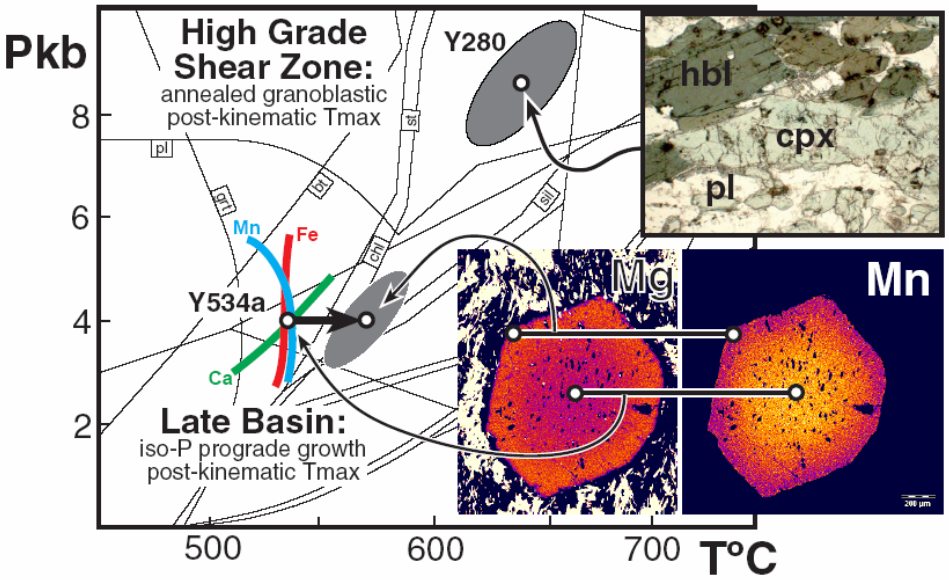
The conductive mantle (observed in the magneto-telluric data) occurs at a depth of around 130 km, consistent with a change from slower to faster shear wave velocities. Is this the base of the Yilgarn’s lithosphere, it is much shallower than the 220 km commonly quoted? Does it predict poor diamond potential from a thin/normal lithosphere?

Metamorphic Report number 4 delivered

Ben Goscombe has been busy compiling the mother of all metamorphic databases. He has undertaken 1385 PT calculation experiments for 481 samples across the Eastern Yilgarn. Calculations of av.PT, av.P, av.T and Fe-Mg exchange T using THERMOCALC v3.2 were undertaken on parageneses with sufficient mineral end-members. These results form the basis of an internally consistent quantitative database with directly comparable P and T constraints across the whole eastern Yilgarn Craton. Prograde conditions and P-T trajectories in 90 samples were determined from garnet core to rim compositional variations, that were interpreted within published metapelite pseudosections with garnet isopleths (*see below*). A large range of conventional geothermometers and geobarometers have been applied to all samples. All results have been compiled into a preliminary database (see Twiki). These results are being used to; (1) constrain P and T in samples with insufficient mineral end-members to calculate PT in THERMOCALC and (2) to independently verify THERMOCALC results.

Summary of preliminary calculated PT conditions (see figure):

- Epidote amphibolites = 520ºC, 6 kb. Prograde burial P-T trajectories.
- Mafic granulites, west Burtville Terrane = 720ºC, 3.5 kb.
- Lower-amphibolite facies EYC greenstones = 500-550ºC, 4 kb
- Mid-amphibolite facies EYC greenstones = 600ºC, 6 kb.
- Upper-amphibolite facies shear zones = 650ºC, 8.5 kb
- Late basin meta-turbidities = 550ºC, 3.5 kb. Tight anticlockwise P-T paths.
- Amphibolite facies Southern Cross Terrane = 550ºC 3-5 kb. Clockwise paths.



Contrasting metamorphic conditions for a high-grade shear zone (Y280) and Late Basin (Y534a)

Garnet cores in the Late Basin have well constrained cores with high temperature post-kinematic rims (see Mn and Mg maps) with little change in calculated pressure between these stages.

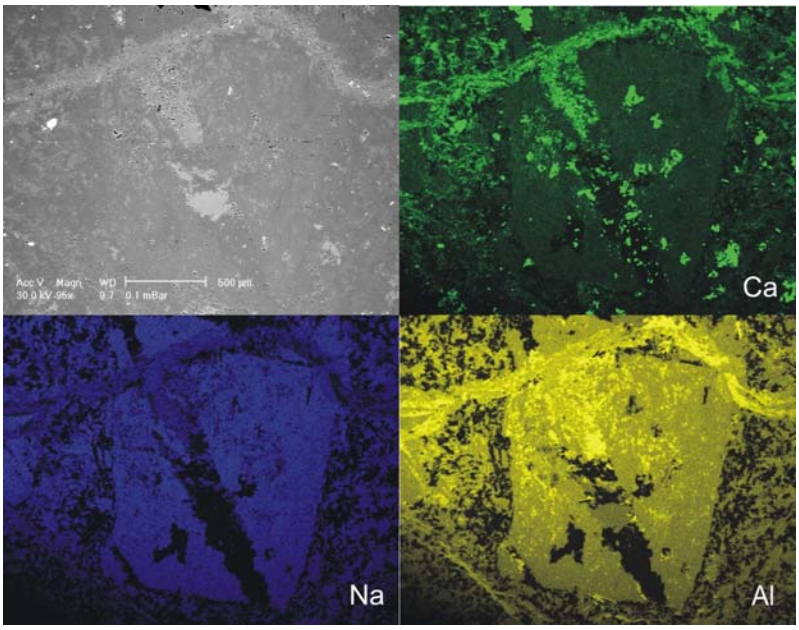
Dating the metamorphism: the little *t* in the PT*t* story

We have attempted to date garnets and hence the metamorphism in the Eastern Yilgarn. Y4 reported previously (Pdt and Dec 2006 report) on Lu-Hf ages, with the apparent old ages interpreted as due to 'inheritance' of Hf from zircon. The Sm-Nd system is not affected by zircon occurrence. These dates are presented here (*right*). Unfortunately the ages are consistently too young! Roland Maas says "*It is also quite odd that Lu-Hf and Sm-Nd ages correlate perfectly. If things are screwed up, either geologically or analytically, what could possibly produce such a pattern?*"
They mimic very well the many of the attempts using Ar-Ar and Rb-Sr that consistently gave ages in the same range. The "young" Ar-Ar and Rb-Sr results have generally been thought of as reflecting either 'slow cooling' or open-system behaviour. There are several examples of 'young' ages coming from the Canadian Abitibi. More work is needed to understand these isotopic systems.

Sample	SmNd	LuHf
530	2561±11	2681±9
534	2547±17	2675±7
667	2593±13	2698±13
690	2610±16	2712±13

For more information contact ben.goscombe@adelaide.edu.au

Probing the mica story: linking spectra with mineralogy



Tony Roache (ER at St Ives) showed at the PDT in November 2006 that the Bellerophon deposit has gold hosted just inside the muscovite/paragonite domain, but proximal to the phengite domain (in white mica space). In other cases around the Yilgarn the fluids team have demonstrated that gold mineralisation is located in the phengite domain but proximal to the change into muscovite/paragonite. Understanding these relationships (and the spectra that map them) is a very useful tool to focus drilling around this domain boundary early in a drill programme.

Left: Probing chemistry of the alteration mineralogy

Work this quarter by Tony Roache has been successful in (more robustly) linking the chemical composition of the alteration mineralogy with the spectral information (*do the spectra really read the right chemistry?*), and also determining the paragenetic sequence of the fluids. These results are being integrated with the structural and chemical architecture – *in other words by reading the chemistry in the spectra we are actually able to make a call on a particular structure and its significance for gold mineralisation*. Tony has undertaken a microprobe study of feldspar and white mica chemistry from across a paragonite-bearing (acid) shear zone within Black Flag Beds in the footwall to the Argo deposit.

Some of these results are:

- The foliation within the shear zone comprised calcic plagioclase (An46 Ab54), and the matrix and feldspar clasts contained albite. Na and Ca compositional maps show the spatial relationship between the sodic and calcic plagioclase. This work is tracking the relative timing of the Na metasomatism and the subsequent Ca metasomatism, which is critical to the fluid story.
- Coexisting paragonite and muscovite-phengite overprinted both plagioclase phases, with paragonite mainly restricted to calcic plagioclase foliations.
- The greatest reflectance in the Al compositional map displays areas of white mica. Calcite, dolomite, chlorite and tourmaline that are temporally associated with white mica were also analysed.

For more information contact Anthony.Roache@goldfields.com.au

Deliverables next quarter

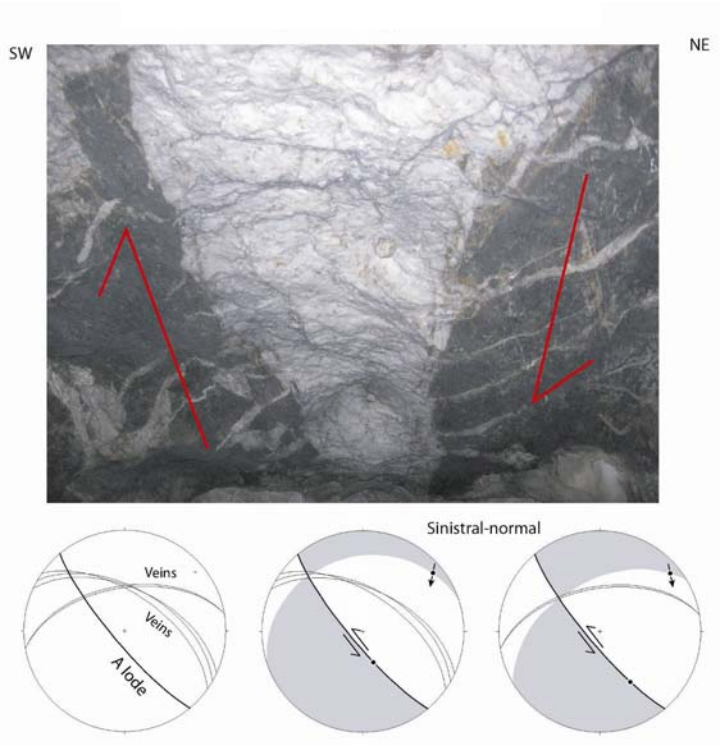
Most activities next quarter will be focussed on completing the research phase of the project and ensuring knowledge/data gaps are filled. A major project meeting 2-4 May (Perth) will bring the team together to workshop the science and plan the completion and final delivery of the project to sponsors.

Expected outputs next quarter include:

- Numerical simulations testing the Laverton restraining bend architecture
- Metamorphic report # 5
- St Ives structure and integrated fluids report
- Site visits (in addition to Embedded Researcher studies on site)
- Reports on new detrital-zircon age data for Late Basins and Black Flags, and whole-rock geochemistry and logging at St Ives and Agnew
- Draft paper on the magneto-telluric data and results

Kinematic and geometrical linkages at St Ives Camp

John Miller (UWA-CET) has made significant advances in the architectural understanding of the St Ives camp. A ppt presentation is available on Twiki for details. The highlights of this new work include:



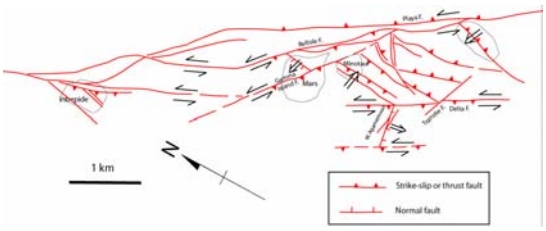
A-Lode with sinistral normal kinematics in the Beta-Hunt Ni mine at Kambalda

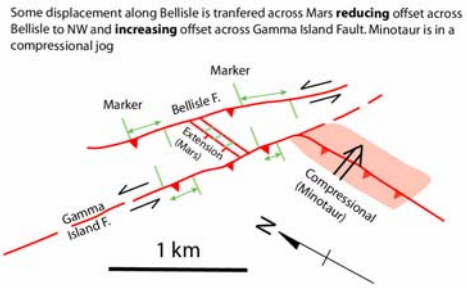
1) a 1:25000 scale interpretation from Greater Victory to Kambalda dome – this highlighted tranpressional and transtensional zones during the gold event
2) new kinematic results from Delta North, Thunderer, A lode (Beta-hunt mine), Temeraire and also integrated existing data (pit maps and thesis work) from Revenge, West Agamemnon, Victory, Mars, Delta, Minotaur, Lifeboat)
3) new kinematics integrated at the 1:25000 scale – this proves the inferred transtensional segments at the 1:25000 scale are sinistral-normal features (e.g. A-lode) (*see picture to left*)
4) highlighting the variations in intrusive rocks (dykes) and the subsequent control they have on 'flat' lodes, transfer faults and shear failure of key fault segments during the main gold event
5) recognition that the dykes changed the 'D2' architecture prior to reactivation during the gold event (i.e. it is not just a reactivated 'D2' system the intrusions are an additional complication and control on gold lodes)
6) interpretation that the dykes reflect a radial stress field directly above the major domes at depth in the seismic – away from these domes they have a more consistent opening direction (locally – this direction varies along strike)
7) changed paradigm where previous work highlighted the transpressional jogs (e.g., Victory) but the system has a large number of extensional step-overs that are sites of mineralisation (deposits) – inferred examples are Lifeboat, West Agamemnon and Mars
8) recognition of deposits in extensional sites, suggesting that gold precipitated due to either;
    a. a pressure drop,
    b. reactive rock types or
    c. fluid mixing – a seal is not always required.

The significance of this work is that a disparate collection of deposits are now geometrically and kinematically linked in time and space.

Contact jmmiller@cyllene.uwa.edu.au for further information

Revised Architecture for St Ives

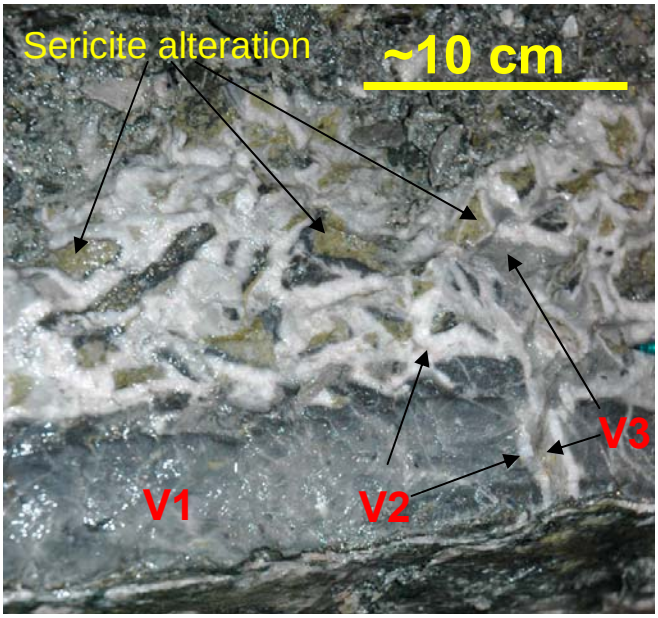




AngloGold Ashanti - Sunrise Dam visit - February 2007

Members of the pmd*CRC Y4 project visited AngloGold Ashanti offices in Perth on the 26-02-07 to discuss targeting in the Laverton region with a specific focus on the Sunrise Dam region. The following two days were spent at Sunrise Dam Mine gaining an overview of the current targeting needs and visiting key locations within the underground workings. The aim of the trip was to formulate a work plan for the future research directives.

A presentation was made to the SRD Management Committee on the current research findings from the pmd*CRC Y4 project, and more applied presentations were made to the mine geologists relating to both mine and regional scale targeting criteria.



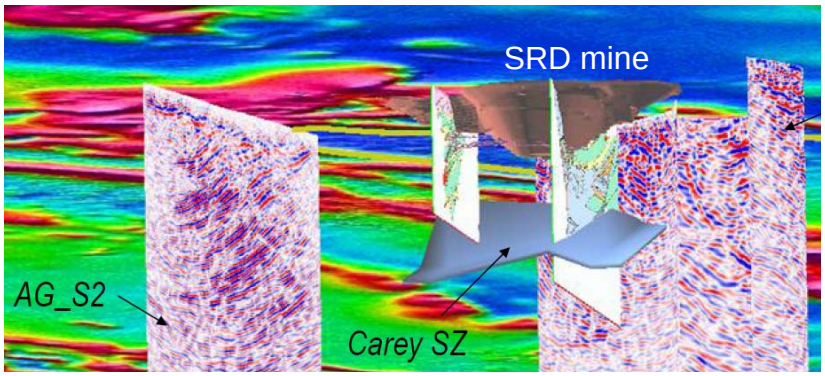
A visit to the ultra-high grade Watu Shear showed a complex vein paragenesis (*left*) that can be interpreted by the following sequence:

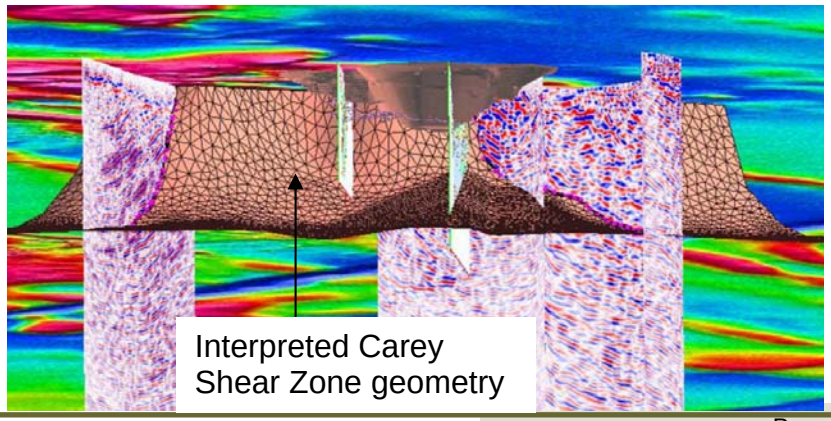
1) Sericite alteration ('D3'?)
2) Coherent grey quartz vein (V1), fault parallel ('D3' probable?/ 'D4'?), fractured and brecciated at its margins
3) Intense brecciation (angular sericite clasts and minor V1 ? clasts), probable 'D4' dextral
4) Quartz carbonate veins (V2) developed in open space fill, cross cutting V1 vein Chalcedonic grey quartz (V3)

Paul Henson (GA) has integrated the aeromagnetics, detailed stratigraphic sections (from Mark Doyle - AGA), seismic reflection, and drilling data to build an extended 3D surface of the Carey Shear Zone (*triangulated brown surface in lower image*).

This deep structure, beneath the better understood Sunrise Shear Zone, is a challenge for the Sunrise Dam mine exploration. The Y4 project has provided the sponsor a better image of the likely geometry of this structure and has defined a number of targets. View in both images (*to right*) is from slightly below present land surface up to the east.

For further information contact paul.henson@ga.gov.au





List of project events for the quarter

1. Project meetings and Fieldwork

Name	*Date*	*Venue*	*Number of Researchers*	*Number of sponsors*
Fieldwork JW, PN, TR, JMM at SIG	05-09/02/07	St Ives	4	3
Fieldwork RS	5-16/02/07	St Ives		
Fieldwork PN, JC, PH, RC at SRD	27–28/02/07	SRD	4	2
Fieldwork RS and JM	26-30/02/07	St Ives	1	
Fieldwork SIG, PN, JW, TR	12-16/03/07	St Ives	3	3
Fieldwork RS	30/03-05/04/07	Agnew	1	
ICP-MS fluid inclusion analysis by KP	26/02 – 04/03/07	Leeds	1	0

2. Workshops

Name	Date	Venue	Number of researchers	Number of sponsors
Fluids JW, PN, CY, JC, TR	15/03/07	Kalgoorlie	5	0
3D target WS	20/02/07	ARRC, Perth	3	3

3. Conferences/Symposia

Name	Date	Venue	Number of researchers	Number of sponsors
Prospectors and Developers Assoc of Canada (PDAC) RB, NW	4-7/03/07	Toronto, Canada	2	Many from BHPB, AGA, Barrick, GSWA
Lithosphere – petrological and geophysical workshop (RB)	8-10/3/07	Ottawa, Canada	1	2

4. Shortcourses

Name	Date	Venue	Number of researchers	Number of sponsors
Peter Neumayr, and John Walshe continue to provide on-site training and development for sponsors		On site: St Ives	variable	variable
Peter Neumayr, John Walshe presentation at CET MSc short course	26/02/07, 02/03/07	Perth, UWA	2	

DID YOU KNOW?

Recent robust P-T calculations by Ben Goscombe have shown that the Eastern Yilgarn has locally recorded pressures of up to 8 kb (~25 km depth) for super-crustal rocks in 'external' granitic gneisses. The process of such deep burial and exhumation is being investigated.