*pmd*CRC* Quarterly Report

January 2005 to March 2005

Stage 2, Project Y4
Name of Project: Concepts to targets: a scale integrated mineral systems study of the Eastern Yilgarn Craton

Project leader: Richard Blewett

Project team:
GA R. Blewett, T. Brennan, K. Cassidy, D. Champion, K. Czarnota, B. Goleby, P. Henson, M. Nicoll, Geophysicist (to be appointed).
UWA Louis Gauthier, Klaus Gessner, Steffen Hagemann, Johanna Hodge, Mehrdad Heydari, Klaus Petersen, Peter Neumayr
JCU James Cleverley, Nick Oliver, Gerard Tripp.
CSIRO Alison Ord, plus one full time equivalent modeller
Uni Melb Mark Kendrick, Roland Maas, John Miller, Dave Phillips, Tony Roache, Carl Young, embedded researcher (Wallaby) to be appointed
Monash Anthony Morey

Partner institutions: Geoscience Australia, The University of Western Australia, CSIRO EM, Monash University, The University of Melbourne, James Cook University

Contents

1. Introduction / aims of project:

The principal outcome for the Y4 project will be a multi-scaled 4D understanding of the world-class orogenic gold mineral system of the Eastern Yilgarn. A measure of our success will be the successful application of this understanding to the predictive targeting of undiscovered resources in near mine areas, as well as concepts and hypotheses that can be applied to targeting in data-poor areas.

To achieve this outcome the project aims to produce a series of well-constrained 3D maps at a variety of scales that integrate the structural–stratigraphic history and the alteration–fluid history with the evolution of the architecture. Using this scale integrated approach, the project will develop criteria to improve area selection, near mine exploration and ore shoot identification. It is envisaged that many of these criteria will apply in a generic sense to other terranes.

The project aims to develop a range of hypotheses from the geodynamic (whole of orogen to base of lithosphere) scale to the mine-site specific scale. These hypotheses will be tested with numerical models that will have local as well as generic applications.

The project will work closely with the sponsors to ensure that the research results and deliverables meet their needs and expectations, have an impact and deliver tangible value for predictive mineral discovery.

The project has fifteen (15) key deliverables, each with a set of milestones.

1. New time-space event history database, charts, and maps

2. **Reports on an updated structural history/stratigraphy (unravelling the D's)**

Work in progress

- Targeted structural mapping in Kalgoorlie region (Gerard Tripp)
- Structural compilation and data reduction for Bardoc tectonic zone (Anthony Morey)

3. **Maps and reports of regional metamorphism and PT*t* history integrated with structural and alteration history**

4. **Report on likely geodynamic models of the Yilgarn, with appropriate tests and possible analogues, and a workshop**

5. **3D maps/GIS of specific districts to be build on Y2 regional 3D map (*Laverton, Kalgoorlie-Kambalda, Agnew*)**

Work in progress

- Kalgoorlie-Kambalda 3D map stratigraphic infill ongoing. Progress to date ~30% complete (Terry Brennan)
- Regional solid geology GIS Qa/Qc process completed with checking labels and polygons from the AMIRA granite map merge with Y2 solid geology map (Richard Blewett)
- Corrections in progress
- Preparation of STOMP paper abstract on dome architecture and fluid flow (Paul Henson)

6. **Map and report on the early extensional architecture and history**

7. **Reports on the character of key faults, especially the deep-tapping 'cracks'. Acquire new data (*MT and tomography*).**

Milestones

- Morey, A.A., Weinberg, R.F., and Bierlein, F.P., (*in press*), Deformation history and multiple mineralisation events within the Bardoc Tectonic Zone, Eastern Goldfields, Western Australia, In Mao and Bierlein (eds), 8th Biennial SGA meeting, extended abstracts volume

Work in progress

- Discussions and planning beginning with Graham Heinson of Adelaide University on MT survey (Bruce Goleby)
- *Draft manuscript in progress:* Morey, A.A., Weinberg, R.F., and Bierlein, F.P., The relative timing of deformation and gold mineralisation within the Bardoc Tectonic Zone, Eastern Goldfields, Western Australia: Implications for multiple gold mineralisation events within the one shear system (Anthony Morey)

8. **Report on an improved geologically intelligent geophysical inversions, supported by a rock property database**

Work in progress

- Early gravity inversion results to WMC from the ground gravity survey they did over Perseverance in December. Having some successes, and the local-scale inversions seem to be picking some contacts within the greenstone package, which has only encouraged WMC to ask for more (Nick Williams)
- Ongoing course work for PhD fulfilment (Nick Williams)

9. **Reports and chemical models on the end-member fluids (magmatic, basinal, meteoric, metamorphic, mantle?)**

Work in Progress

- Klaus Petersen has continued to constrain end member fluid compositions in particular focussing on the reduced fluid end members at St. Ives

- Joanna Hodge measured fluid inclusions of all stages of veining and alteration of the New Celebration deposit to characterise all different hydrothermal fluids in the deposit and the Lefroy fault zone. Further, samples were selected and characterized for detailed whole-rock multi-element geochemical analysis to fingerprint different alteration styles.
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Results

The research was predicated on earlier research (Walshe et al., 2003) that suggested large-tonnage, high-grade gold deposits in the Eastern Goldfields Province resulted from the interplay of two chemically contrasting fluid systems. From work in the project it is now recognized that:

- The gold systems contain multiple fluid reservoirs and pathways.
- Gold deposition is related to chemical gradients generated by mixing of fluids of contrasting chemistry.
- Architecture controls the mixing of contrasting fluids

- At least three main fluid types/reservoirs are now recognized (Figure 1):
    1) Ambient aqueous carbonic fluids with the CO2 largely derived from the greenstone host sequences,
    2) Oxidized magmatic fluid sourced from 2665-2650 Ma mafic and syenitic magmas; and
    3) Chemically contrasting highly reduced fluids inferred to have been sourced from the deep crust or mantle.
- The recognition of these three "end-member" fluid types has come through cross-scale integration of geological, geophysical and geochemical data (mineralogy, paragenetic relationships, fluid inclusions and stable isotopes). Fluid inclusion studies at St. Ives provide evidence for rapidly changing fluid conditions with fluctuations from saline H2O-rich fluids prior to gold precipitation, to CO2-rich fluids during gold precipitation, to extremely saline H2O fluids post gold mineralization (Petersen et al., 2005). Distinct fluctuations during the formation of the New Celebration gold deposit from CH4-rich, to H2O-CO2 fluids back to CH4-rich fluids (Hodge et al., 2005) further emphasize the importance of chemically contrasting hydrothermal fluids in the system.
- Interaction of these end-member fluid types and host lithologies produces a wide range of mineralogical and geochemical responses. M358 has begun to decipher these responses in terms of the evolution of the physico-chemical properties of the fluids (temperature, redox state, acidity, salinity, H2S activity, H2O activity) and the significance with respect to the nature of flow paths, location within the architecture, distal or proximal setting to gold zone, depth in the system, as well as the signatures of primary input fluids, exhaust fluids or degraded/background fluids.

10. Reports, maps and databases on integrated mineral paragenesis and architecture and chemical modelling for selected camps and deposits

Milestones

- John Miller has championed the use of Leapfrog 3D software to interrogate the architectural controls on alteration and mineralisation. Together with Peter Neumayr and Klaus Petersen, a 3D model for the Victory-Defiance area at St. Ives has been developed and interpreted with respect to chemical architecture, chemical gradients and applications to exploration targeting.

Work in Progress

- The activities focussed on developing a 3D model for the Victory-Defiance area. This model is fundamental in guiding further sampling for stable isotopes and multi-element geochemistry as well as fluid inclusions to constrain endmember compositions. Further, the model is used to constrain the chemical and structural architecture to identify reduced and oxidized fluid conduits and zones of highest chemical gradients (i.e. zones which are, based on chemical grounds, likely to host high grade mineralization). The model has been interpreted and interpretations extrapolated outside the model area. This allows predictions of targets in areas which are currently the exploration focus of St. Ives Gold Mining Company. The results have been reported to site in formal presentation as well as in informal discussions with member of the target generation group at SIGMC (John Walshe, Peter Neumayr)
- Work has begun on developing a new MERIWA project to support the embedded researcher program through 2005-2007 (John Walshe, Peter Neumayr)
- Susan Drieberg has not renewed her contract beyond June 2005 and a new embedded researcher will be appointed to the Wallaby site in the Laverton region for the new project. Susan will work at ARRC through the end of June to complete her geochemistry programme
- Peter Neumayr, John Miller (University of Melbourne) and John Walshe spent time on sites working with the embedded researchers on architectural and geochemical issues
- The Conqueror geochemical sampling program was completed in January. Structural analysis of drill hole CD10095W1 was completed and an initial draft report that includes structural and PIMA/HyLogger data from the Conqueror sections has been produced (Tony Roache)
- Louis Gauthier continued interpretation of multi-element geochemistry of the complete suite of porphyry dykes present at the Golden Mile and integrated the interpretations with detailed petrographical observations and field relationships. Furthermore, the manuscript on the structural setting and timing and gold mineralization at the Golden Mile was completed in February.
- Mherdad Heydari concentrated on detailed petrographical studies at the alteration in ultramafic rocks of the Otter-Juan mine. Further he selected and documented in detail samples for multi-element whole rock geochemistry to fingerprint different alteration styles.
- R. Gordon's structural compilation and analysis of oriented drill-hole data from the Greater Revenge Area was reviewed, and is subject to additional review and additions. The ultimate goal is to gather the mean orientations of bedding and foliations from a broad cross-section of St Ives Camp drill holes and insert them into a 2D GIS. These data would be compared in terms of their geometry to the 3D models at Conqueror, and also at Revenge and Junction in the future. Further work is to be deferred until May (Peter Neumayr)
- Meetings with Marilyn Ward, Hans Georgi and Tim (Datamine) looked at the conversion of backs mapping from MicroStation into Datamine. Geological surfaces will be extracted from the mapping by wire-framing string data, and then will be overlain on Au distribution (Tony Roache)
- The quality assurance program to correct numerous erroneous multi-element geochemistry records is near completion and is awaiting final validation. Part of this program included the refinement of a procedure to extract the data from the database in a format useful for 2D and 3D modelling (Carl Young)
- A Kundana alteration study has been designed to evaluate the geochemical signature of the mineralisation in the camp and determine what techniques may assist in vectoring

towards ore. The program will involve the collection of additional samples to those already collected, for a variety of analyses, which will need to be constrained paragenetically and modelled in 3D (Carl Young)

- Placer Dome is currently providing financial support for the development of the 3D Geomodeller package. As there is a need for a 3D modelling tool to handle sparse data points, this program is being evaluated for the Kanowna Belle research project. The program is still in the development stages and testing is continuing (Carl Young)
- The next quarter will involve a more focussed mapping and logging program at Kanowna Belle to take forward the alteration study. This work will be balanced with geochemical processing of the recently acquired data for the Mount Pleasant area, as part of the Generative Team campaign. Other activities in the coming quarter include a short HyLogger workshop and analysis of the HyLogger data, pmd*CRC Ynew workshop, Technical Review meeting within Placer Dome, and continued work on the Kundana project (Carl Young)

Results

- Contribution to Placer Dome Generative Team at Kanowna Belle included a re-assessment of the procedure for defining exploration targets, which involved the modification of the previous targets in the Jackson-Perilya project. In conjunction with this re-assessment, the results of stable isotope analyses were integrated to improve ranking of potential targets (Carl Young)
- The worksheet for calculating the mineral molar abundances from the multi-element chemistry has been revised to handle a greater number of mineral combinations, and should be completed in the next few weeks. In its current form, the worksheet can be directly applied to most of the St Ives Camp stratigraphy, whereas previously the worksheet was built to only deal with the typical Kanowna Belle stratigraphy (Carl Young)

- Deposit-scale studies at Kanowna Belle, the Victory–Defiance Complex at St Ives, and the Wallaby deposit are providing a detailed understanding of the architectural and geodynamic controls on mineralogical zoning, chemical gradients and the locations of gold deposits.
- Figures 3 and 4 illustrate the main architectural controls on the gold deposits and iron-sulfide-oxide assemblages of the Victory–Defiance Complex, St Ives. The model highlights
    - A series of steeply N-dipping E-W structures that appear to have been the pathways of the highly reduced fluid,
    - N-S trending, steeply dipping structures that were the pathways of highly oxidized fluids, and
    - The relatively flat-dipping Repulse Fault that acted as a seal on the system.
- This geochemically constrained and architecturally integrated model is aiding targeting both in the Victory-Defiance area as well as further a-field in the St Ives camp. (Peter Neumayr dot points above)

11. Reports on integrated numerical models of fluid flow for generic and site specific scenarios

12. Regional footprint maps of alteration and fluid flow based on geochemistry, ASTER, HYMAP etc

Milestones

- ASTER data acquired and available for mineral mapping

Results

- Tony Roache attended a one-day PIMA workshop with Sasha Pontual on the 15th Feb. Re-processing indicated that it is necessary to inspect individual spectra within TSG, to be able to discriminate between carbonate, biotite and chlorite. A start was made on the PIMA-analysed holes from the Conqueror sections, using the manual processing method in TSG.

13. Map the chemical and PT gradients for selected sites (e.g., Wallaby, Sunrise, St Ives, KB), and regionally

Work in progress

- HyLogger data from Argo and two holes from the Conqueror sections – CD10662 and CD1979 – were reviewed. Two telephone conferences with the CSIRO Mineral Mapping Technologies Group on the 9th and 22nd March served to gain feedback from both sides and to plan the future direction of HyLogger spectral processing.
- A detailed synthesis of these findings and interpretation of other PIMA/structural results will be released in a memo during April.
- Drill-hole Au distributions in the Victory-Defiance area were converted from Datamine to Leapfrog files. The resource geological models from Conqueror were overlain on the Leapfrog-modelled Au distributions to assess geological controls on Au. Follow-up discussions with John Haywood (Resource Geology) will focus on further wire-framed surfaces and their origin (Peter Neumayr dot points above)
- John Miller visited from the 18th to the 22nd of March and produced a lithological model of Victory-Defiance. The mapped distribution of felsic intrusives proved to be the most helpful in terms of defining potential structural trends, particularly an E-W trend that has been identified from magnetic and gravity surveys. John Miller presented a talk of his Leapfrog work at Wallaby, showed preliminary data from Victory-Defiance, and finished with results of the pyrite inclusion dating from Revenge. John Miller, Carl Young (embedded researcher - Placer Dome) and Tony Roache visited East Repulse and Conqueror underground workings.
- Prior to John Miller's visit files for input into Leapfrog were prepared for Victory-Defiance and Mars. Ultimately, the initial Leapfrog model of Victory-Defiance requires further data to test the continuity of lithological trends; therefore, the Mars data was not processed through Leapfrog.
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Results

- One outcome of the spectral processing thus far is the identification of shear zones within felsic host rocks that have a diagnostic low AlOH white mica wavelength.
- These shear zones overprint and spatially replicate the distribution of albite+quartz shear zones, thus are proxies for the distribution of both styles of alteration.
- Albite+quartz shear zones are genetically related to amphibole+biotite+carbonate alteration within CD10662.
- The HyLogger downhole mineralogical distribution in CD10662 shows that amphibole, biotite and carbonate surround the broad silicified zone from 532-817m.
- Petrographic interpretation from thin-section and hand-specimen indicates that the muscovite+quartz+calcite+chlorite+pyrite alteration within the silicified zone is an overprint of a pre-existing albite+quartz alteration zone with an associated amphibole+biotite+carbonate selvedge.
- At Victory-Defiance, the mapped distribution of felsic intrusives proved to be the most helpful in terms of defining potential structural trends, particularly an E-W trend that has been identified from magnetic and gravity surveys (Carl Young dot points above)

- Camp-scale variations in sulphide, oxide, and silicate mineralogy, S isotopes in sulphide minerals, and C&O isotopes in carbonate can be interpreted in terms of interaction (mixing) between the end-member fluids in the system (Neumayr et al., 2003, 2004a,b,c

and 2005). Fluid-rock reaction processes are important locally and within source regions of the fluids, but the dominant process driving camp-scale gradients, notably in redox and acidity, appears to be fluid mixing.

- High grade gold occurrences have been shown to relate spatially to gradients in redox (as determined by iron-sulphide-oxide mineralogy, i.e., the relative distribution of hematite, magnetite, pyrite, pyrrhotite) and to pH gradients as defined by white mica mineralogy (muscovite, paragonite, phengite).
- Figure 2 summarizes the variation in white mica mineralogy in the Kanowna Belle district. The short wavelength domains (blue = muscovite/paragonite assemblages) and associated trace element geochemistry reflects acidic and reduced fluid conditions that arise from mixing of deep mantle fluid with ambient fluid (Figure 2; inset).
- The muscovite/paragonite (acidic) domains are not favoured locations for gold precipitation but do help define pathways along which the deep fluids moved into the upper crustal architecture. The gradient domains from muscovite/paragonite to phengite are favourable sites for gold occurrences. (Peter Neumayr dot points above)

14. Reports on the integrated structural controls of ore shoots with the regional framework, linked to alteration and mineralogy (e.g., Wallaby, Sunrise, St Ives, KB)

Milestones achieved

- 16th and to 18th March – onsite Kanowna-Belle (Placer)
- 19th to 23rd of March – onsite at St Ives (Gold fields)
- Wallaby mapping and Leapfrog work delivered as a presentation to:
  - Anglogold (Mike Nugus) at Canberra (1st February)
  - Placer exploration geologists at Paddington (17th March)
  - Goldfields mine and exploration staff at Kambalda (22nd March)
- St Ives Leapfrog modelling delivered as a presentation:
  - to Goldfields staff on the 22nd March (above John Miller activities)

Work in progress

- Pyrite dating of Revenge, Kanowna-Belle, Fimiston Lodes, Wallaby, Mount Charlotte completed (laser heating and crushing experiments) (work done intermittently over January and February)
- Leapfrog modelling of gold and rock types for Conqueror area at St Ives done from 1st of February to 23 rd of March (most of it done onsite at St Ives). Digital output transferred to Peter Neumayr, embedded researcher Anthony Roache and Klaus Petersen and is now integrated with their work programme
- Underground/open pit field trip undertaken at East Repulse, Conqueror and Victory defiance on 22nd of March
- Leapfrog modelling of gold, rock types and alteration of the Kanowna-Belle deposit done onsite at Kanowna-Belle and Paddington on 17th and 18th of March. Digital output transferred to embedded researcher Carl Young and he has integrated that output with his work programme
- Wallaby report on Leapfrog modelling and integrated mapping is currently being written
- Pyrite dating report is currently being written (John Miller above dot points)
- Short report on Kanowna-Belle Leapfrog modelling is currently being complied by Carl Young and John Miller

15. Report on reactive transport models tested against specific sites where paragenesis and structure understood

2. Student details (if applicable)

Activities included within the project deliverables and results

Key Performance Indicators (see guidelines for definitions)

3. Publications.

Please report publications under the following headings

Conference Abstracts

Several papers have been submitted to the STOMP conference in Townsville, based on Y2 and Y3 (Stage 1 projects) work.

Workshop notes

Journal Articles

Periodical/Newsletter Articles

- Date of publication
- Citation

Promotional Presentations

- Tony Roache gave a presentation was delivered to the ST Ives Goldfields March geology monthly meeting. The presentation was entitled, "*Geological research at St Ives: working towards practical outcomes for exploration.*"
- Peter Neumayr gave a presentation at an AIG meeting with the title: "Fluid-rock geochemistry – indicators to ore forming processes and trap sites; Examples from the St. Ives gold camp, Western Australia."
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Visiting Lecture

- Date:
- Title:
- Venue:

4. Training courses

5. Project meetings

Name	*Date*	*Venue*	*Number of Researchers*	*Number of sponsors*
Y4 – project planning and scoping	1-2 February	GA, Canberra	25	4
MERIWA 358 workshop entitled: Navigating the Footprints: Process to Prediction	9th and 10th of February	Kalgoorlie		

6. Workshops

Workshops					
Name	Date	Venue	Number of	Number of	E&T affiliated

			researchers	industry/sponsors	event (Y/N)

7. Conferences/Symposia

Conferences/Symposia					
Name	Date	Venue	Number of researchers	Number of industry/sponsors	E&T affiliated event (Y/N)

8. Shortcourses

Shortcourses					
Name	Date	Venue	Number of researchers	Number of sponsors	E&T affiliated event
John Miller, Peter and John Walshe continue to provide on-site training and development for sponsors	During field visits through the quarter	On site: Wallaby, St Ives, KB, SRD	variable	variable	No

9. Media

Media releases					
Title of media release	Date of release	Originator (Author)	Originator/Author organisation	Subject of the media release	
Media Reports					
Name of report	Date of report	Reporter's name	Media type (print, radio, TV, web, other	Media Organisation	Subject of report

10. Intellectual property created by project

11. Collaboration
    - Immense collaboration between researchers and sponsors. Details may be found in work in progress reports above under each deliverable

12. Issues / problems
    - Sponsors are slow to respond to requests for data. The 3D map of Laverton is behind schedule (as of 6/5/05) as we are awaiting data before solid geology construction and modelling can commence. The project recognises the pressure industry face and the many requests they receive for their time
    - The entire first quarter of 2005 was spent on maternity leave; hence, there are no new activities or project updates to report.
    - For the second quarter of 2005, following her maternity leave, Susan will not be returning to the Wallaby site. She will work at ARRC through the end of June to complete the

interpretation of her geochemistry program and will work to integrate the results of all the research she completed on site during the previous year.

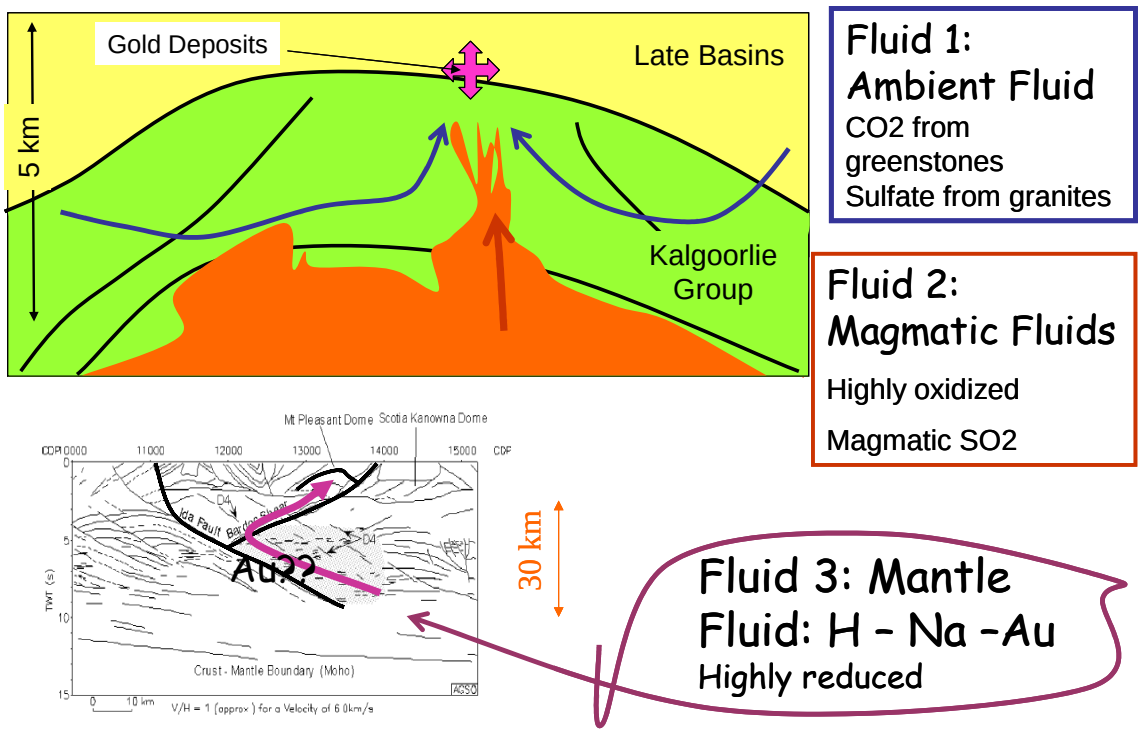
- APPENDIX 1: LIST OF FIGURES

Figure 1: Three types/classes of fluid in the gold systems in the Eastern Goldfields and a schematic illustration of sources/reservoirs/flowpaths in upper crust (top) and the whole crust (bottom).

Figure 2: Map of AlOH wavelength for mica (PIMA data) for the Kanowna Belle district (image courtesy of Placer Dome). The long wavelength domains (red) contain phengite and the short wavelength domains (blue) contain muscovite/paragonite. The Kanowna Belle deposit occurs in the gradient zone where the mica composition changes from muscovite/paragonite (blue) to phengite (red).

Figure 3: Plan view in Fracsis showing architectural control on alteration and gold deposits of the Victory-Defiance Complex, St Ives. Figure 3A shows location of E-W trending (white arrows), steeply N-dipping structures defined by breaks in porphyries (fine red lines; structure 1&2) and E-W trends in porphyries (structure 3). Alteration in E-W domains includes pyrrhotite and pyrite with magnetite absence indicating E-W structures are pathways of reduced fluid. Secondary magnetite is focused in steeply dipping, NW and northerly trending domains (red arrows), indicating oxidized fluid pathways in these orientations. The intensity of magnetite decreases east to west. The locations of the Victory-Defiance and Repulse deposits (Figure 3B) occur at the intersection of E-W structure 2 and NW structures coincident with the change from secondary magnetite to secondary pyrrhotite.

Figure 4: Section view in Fracsis looking North showing relationship of gold lodes (blue zones; 4g/t ore shells), magnetite (red) and pyrrhotite (light blue) to the Repulse Fault and related structures. There is a strong focus of magnetite beneath the Repulse Fault suggesting that this structure acted as an aquiclude to the flow of oxidized fluids. Sulfur isotopes data are consistent with this interpretation.



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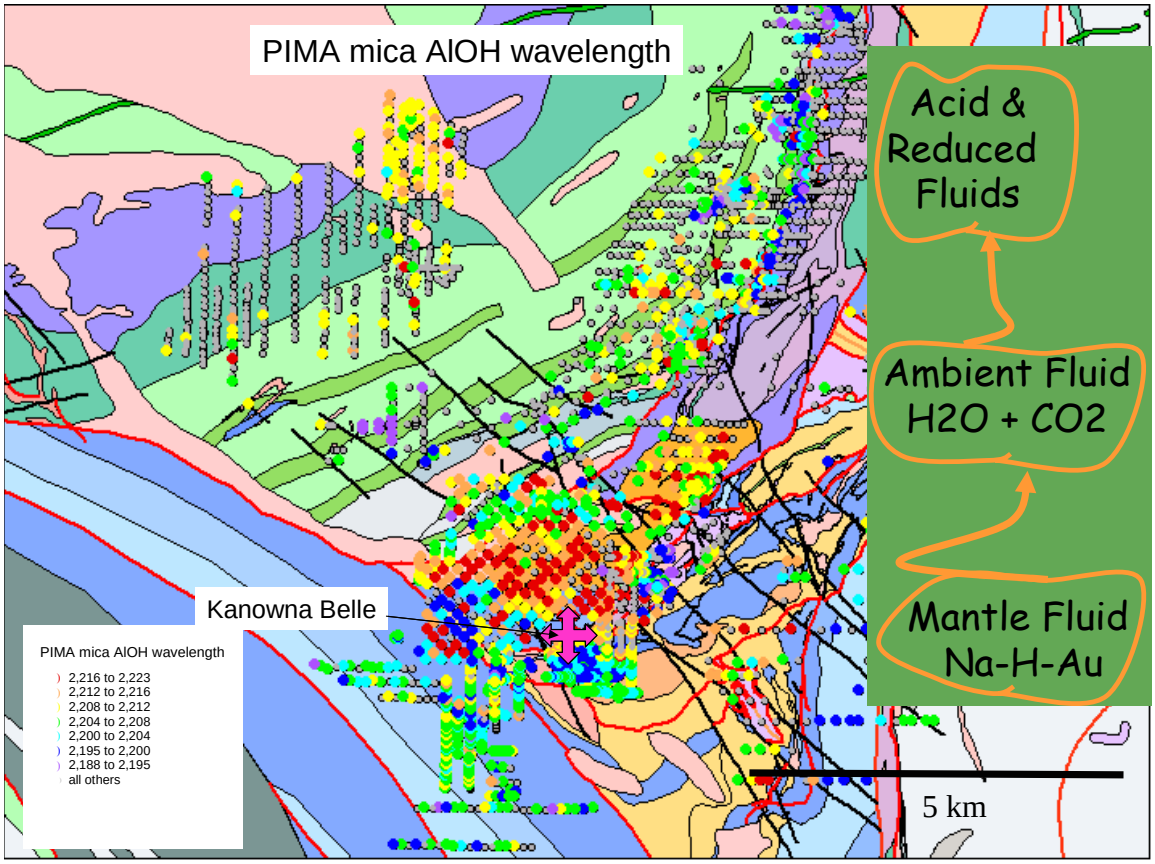

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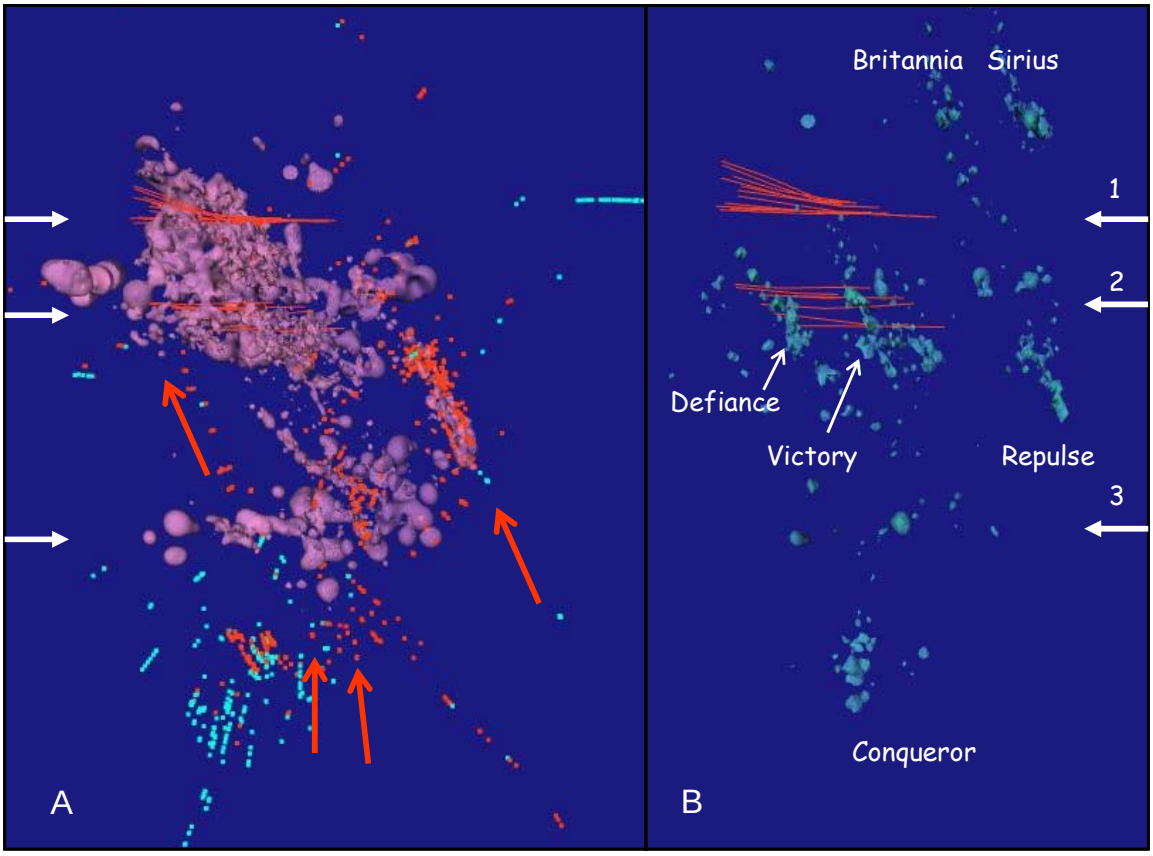

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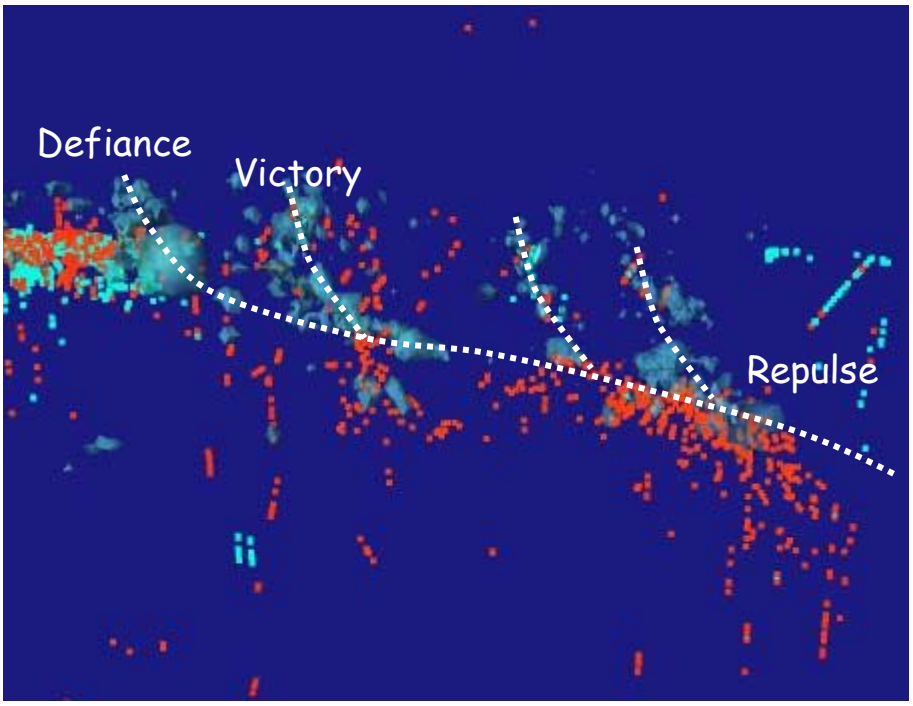

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