The Architecture A1 Project

"What are the fundamental characteristics of mineralised (trans-lithospheric) fault systems?"

Yilgarn Workshop; Perth, December 01, 2003

JAMES COOK UNIVERSITY
THE UNIVERSITY OF WESTERN AUSTRALIA
MONASH UNIVERSITY
THE UNIVERSITY OF MELBOURNE
AMIRA INTERNATIONAL
CSIRO
Australian Government
Geoscience Australia

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Presentation Outline:

I) ***Overview of the pmd*CRC A1 Project***

II) ***Architecture, tectonic evolution, and mineral potential of the Menzies-Boorara Shear Zone***

- PhD Project Anthony Morey (since 02/03)

III) ***Habitat modelling of gold deposits in the Yilgarn Craton***

- Terry Lees (since 07/03)

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A1 Project - Participants

Project Leader: Frank Bierlein, Monash University

Research Team: R. Weinberg, P. Betts, T. Lees, I. Vos, A. Morey (Monash), M. Barlow, B. Goleby, B. Drummond (GA), B. Murphy (Melbourne)

Industry mentors: J. Hronsky (WMC), F. Robert (Barrick Australia), M. Etheridge (SRK), G. Broadbent (Rio Tinto), J. Dugdale (MPI), R. Smith (AngloGold)

Commencement Date: May 2002
Project Duration: 3 years
Linkages: across entire pmd*CRC

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Aim of the A1 Project:

To understand why some fault systems are mineralised, and why others are barren (set of critical parameters?)

Objective of the A1 Project:

Predictive mineral discovery at significantly reduced risk

(fundamental shift)

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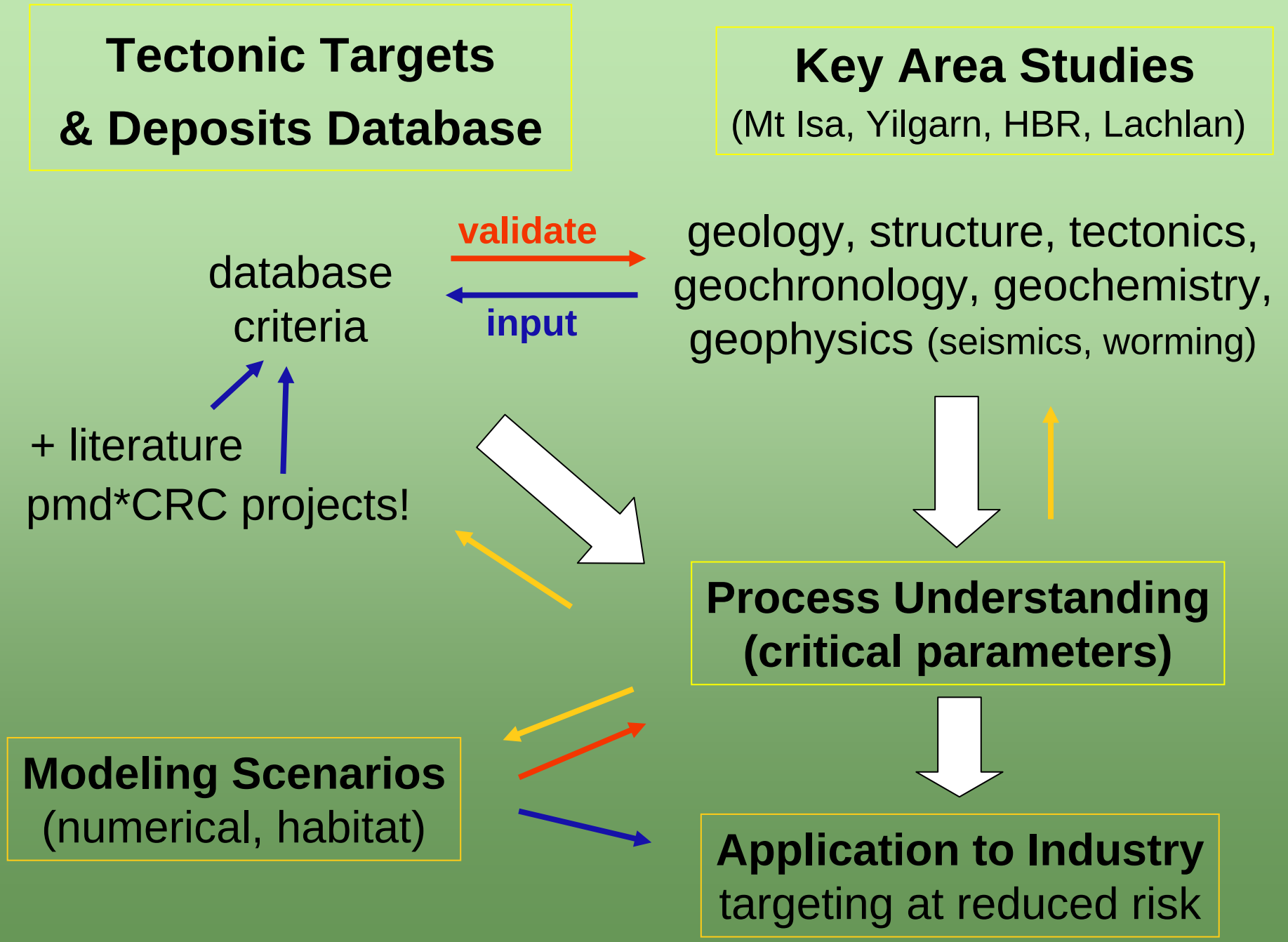
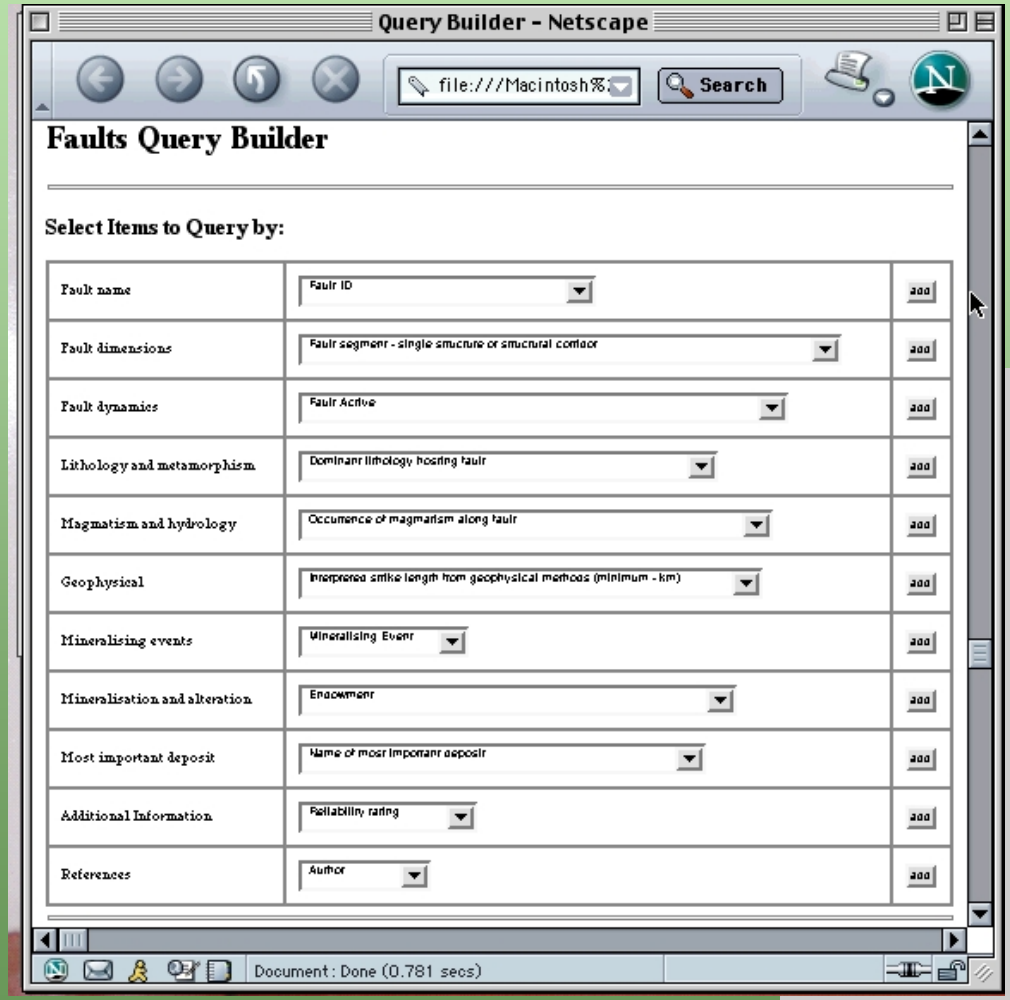
A coherent concept aimed at predicting the mineral potential of major fault systems…

…via a multi-disciplinary approach:

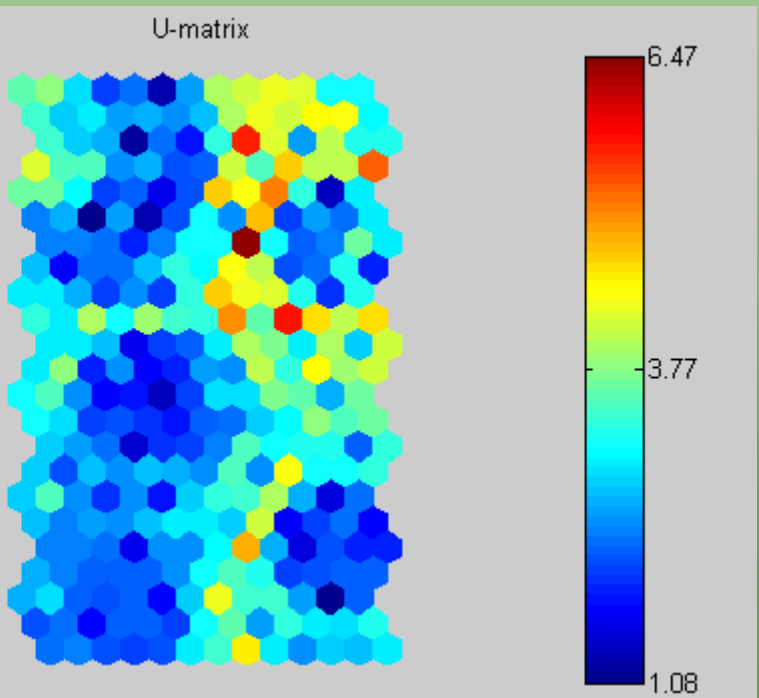

Tectonic Targets
& Deposits Database
Key Area Studies
(Mt Isa, Yilgarn, HBR, Lachlan)
validate
input
database
criteria
geology, structure, tectonics,
geochronology, geochemistry,
geophysics (seismics, worming)
+ literature
pmd*CRC projects!
Process Understanding
(critical parameters)
Modeling Scenarios
(numerical, habitat)
Application to Industry
targeting at reduced risk

Fault ID	Fault or Segment of Fault being documented	Fault segment - single structure or structural corridor	Single fault segments distinguished by	Linkage of single fault segments/relationship between structural elements within corridor	Range of strike length (minimum - km)	Range of strike length (maximum - km)	Width of corridor/ fault zone (minimum - km)	Width of corridor/ fault zone (maximum - km)	Dip geometry of fault
1	Turkestan Suture	single	offset by fault	discontinuous	1000		2	6	listric
2	Atbashi-Inylchek Suture	single	offset by fault	discontinuous	1000				
3	Talas-Ferghana Fault	single	not applicable	continuous	800	900			
4	Atacama Fault Zone	corridor	change in strike	continuous	200	500			
5	Sumatra Fault	corridor	jog separation	discontinuous	50	200	1	20	planar
6	New Guinea Suture	corridor	not applicable	continuous	1000				
7	Gowk Fault	single	not applicable	continuous	100	200	2	4	planar
8	Carlin Trend	corridor	not applicable	discontinuous	50	100	8	10	planar



Tectonic Targets Database

on Twiki; need input!



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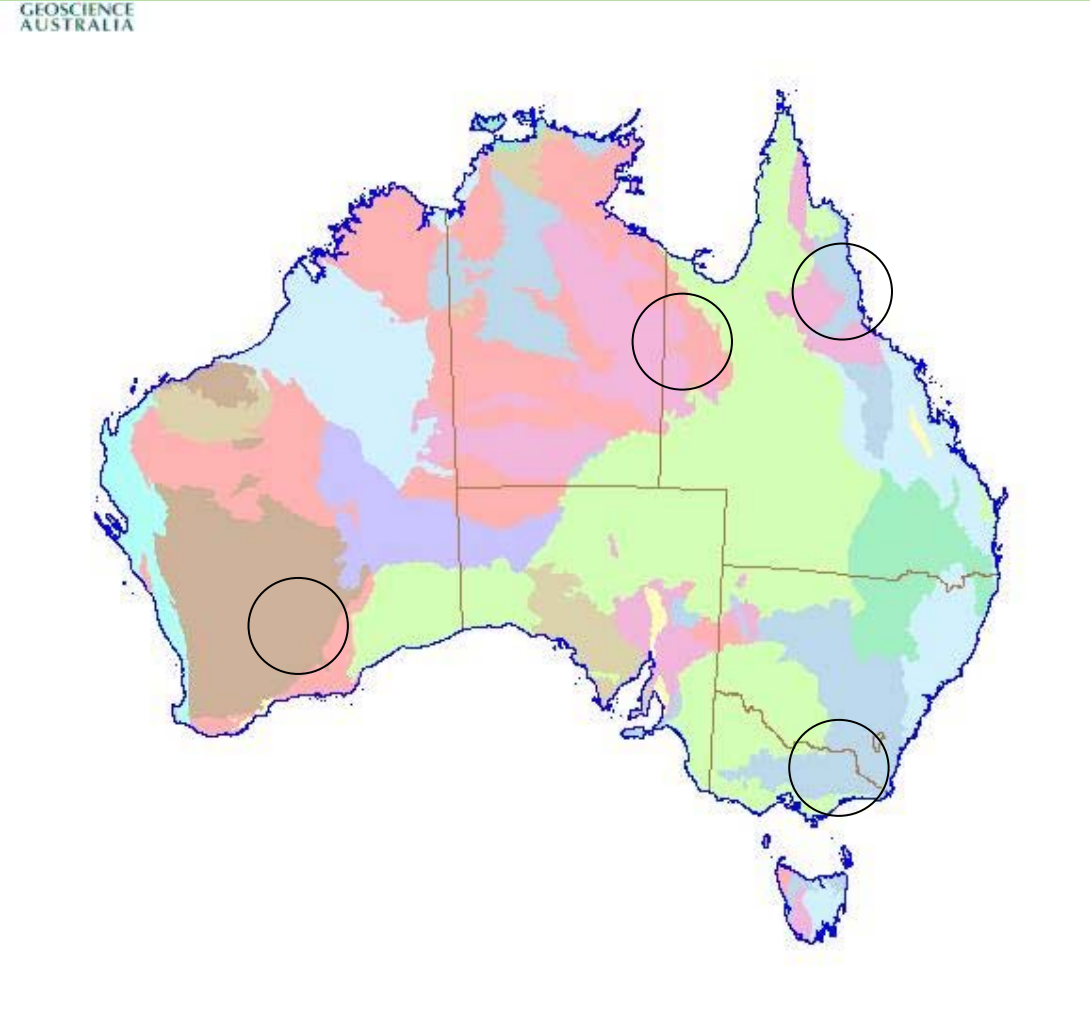
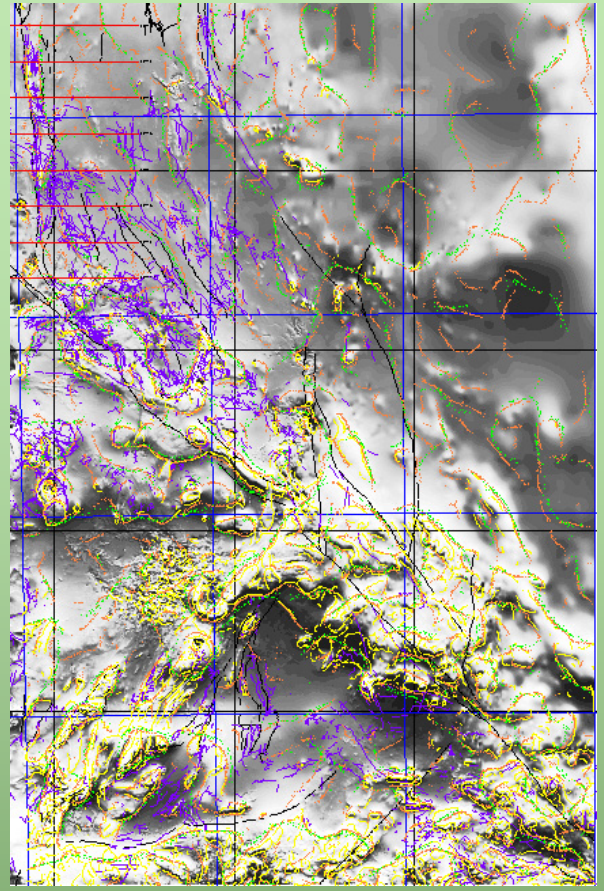
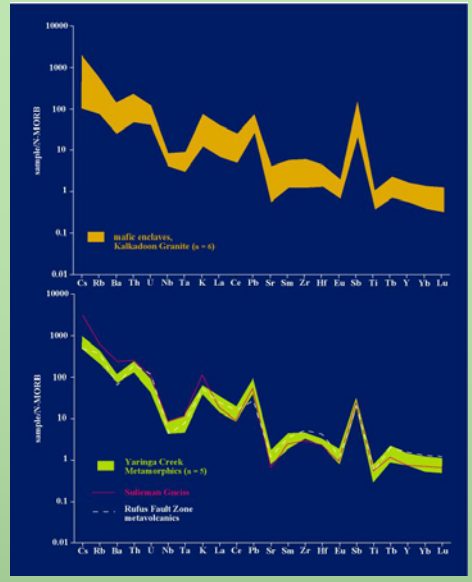
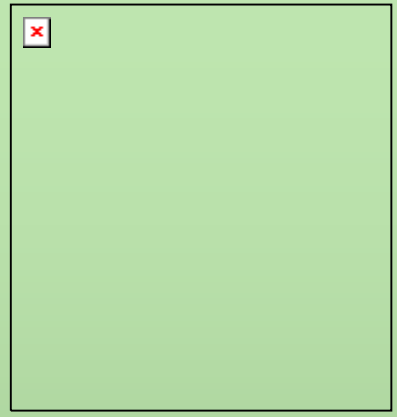
Key Area Studies (HDDT & LDDT):









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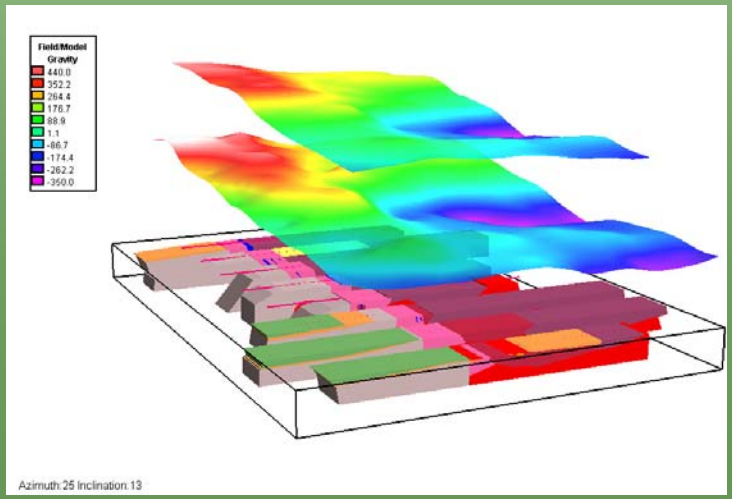
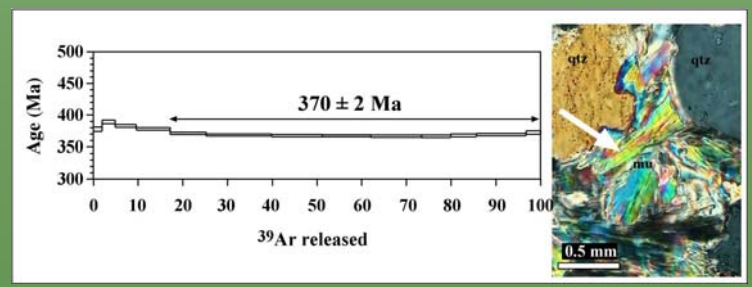
Fault kinematics
structural evolution
geodynamics
geophysics
depth extent
geochemistry
fluids
age…





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…Endowment!

Super Pit

Paddington

The Menzies-Boorara Shear Zone: structural architecture and associated Au mineralisation, Yilgarn Craton

Anthony Morey, Frank Bierlein & Roberto Weinberg

*pmd*CRC School of Geosciences, Monash University, VIC*

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Presentation Outline:

The Menzies - Boorara Shear Zone:

(I) Research goals and study area

(II) Project methodologies

- **Geoscientific methods to be used**
- **Observations and interpretations to date**

(III) Comparison with the Boulder-Lefroy fault system

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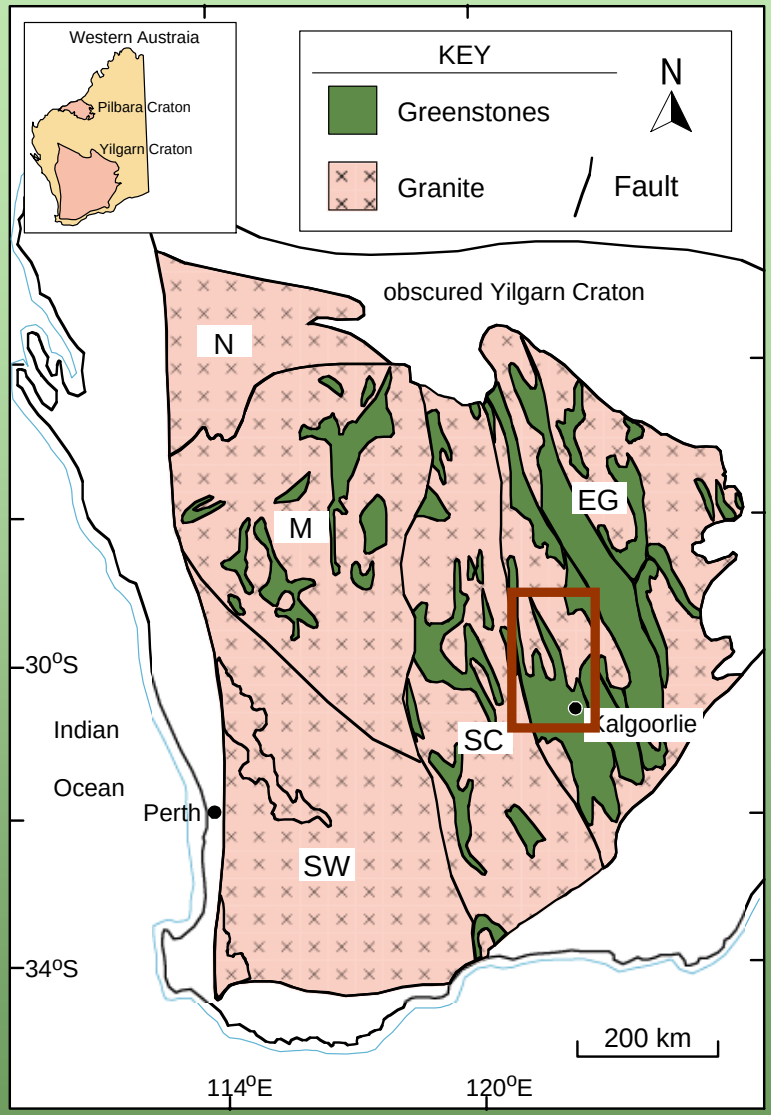
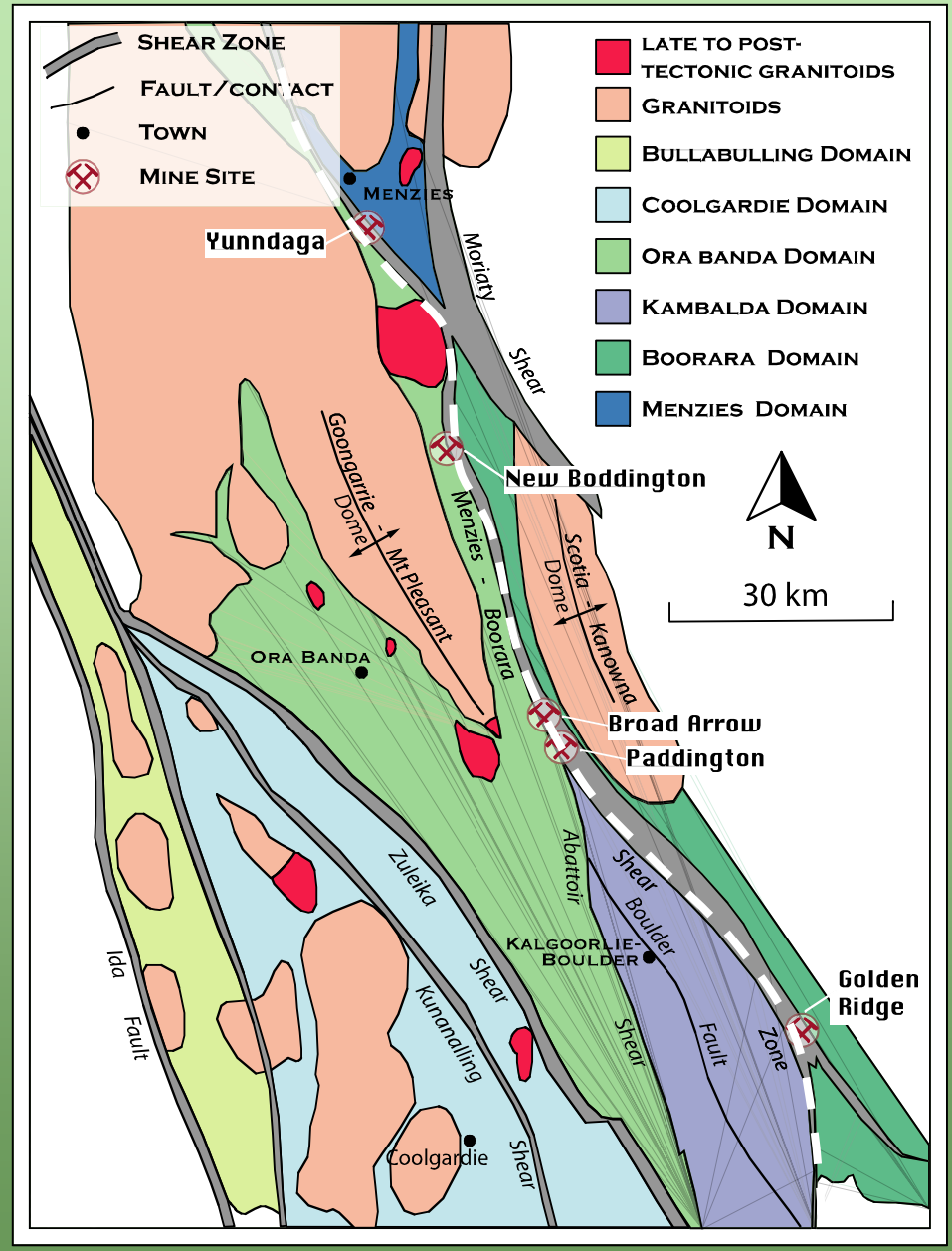
Research Questions:

- **Why is the Menzies - Boorara Shear Zone (MBSZ) less well-endowed than the neighbouring Boulder-Lefroy Fault?**
- **What are the major geological differences between these two shear zones?**

A1, Y2, Y3 projects



After Gee (1979); Myers (1995)



After Witt (1993)

Approach

(I) Relationship between structural evolution of MBSZ and mineralisation

- **Geometry, nature, style(s) and relative timing of deformation-related fluid infiltration events (±Au)**

SCALES: micro ⌦ meso ⌦ regional

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Approach (cont.)

(II) Characteristics of the mineralised and unmineralised fluid infiltration events

- **Mineralogy & alteration geochemistry of *host rocks* & *veins***
  - **Optical microscopy**
  - **Whole-rock analysis (alteration, provenance)**
  - **Fluid inclusion microthermometry (P,T,x)**
  - **Stable isotope geochemistry (O, S, H, C)**
  - **SEM on sulphide assemblages**

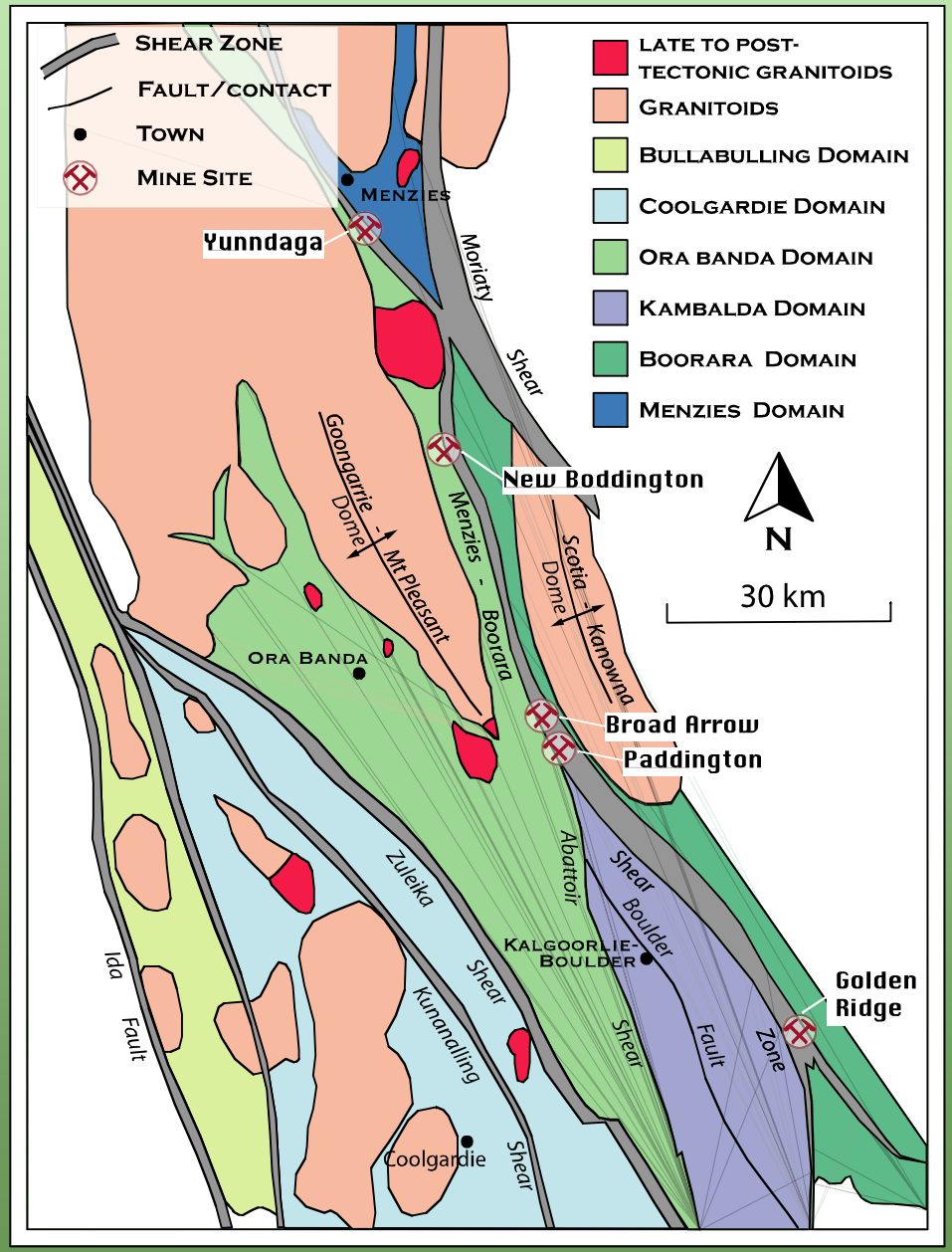
Approach (cont.)

(III) Geochronology of igneous and hydrothermal events

- SHRIMP U-Pb (UWA)
  - ➢ Monazites, zircons - Intermediate to felsic intrusive rocks
- Ar-Ar (H4)
  - ➢ Deformation and hydrothermal events
- Re-Os (H1)
  - ➢ Source and age of sulphide assemblages

(IV) Geophysical interpretations

- In collaboration with Geoscience Australia



After Witt (1993)

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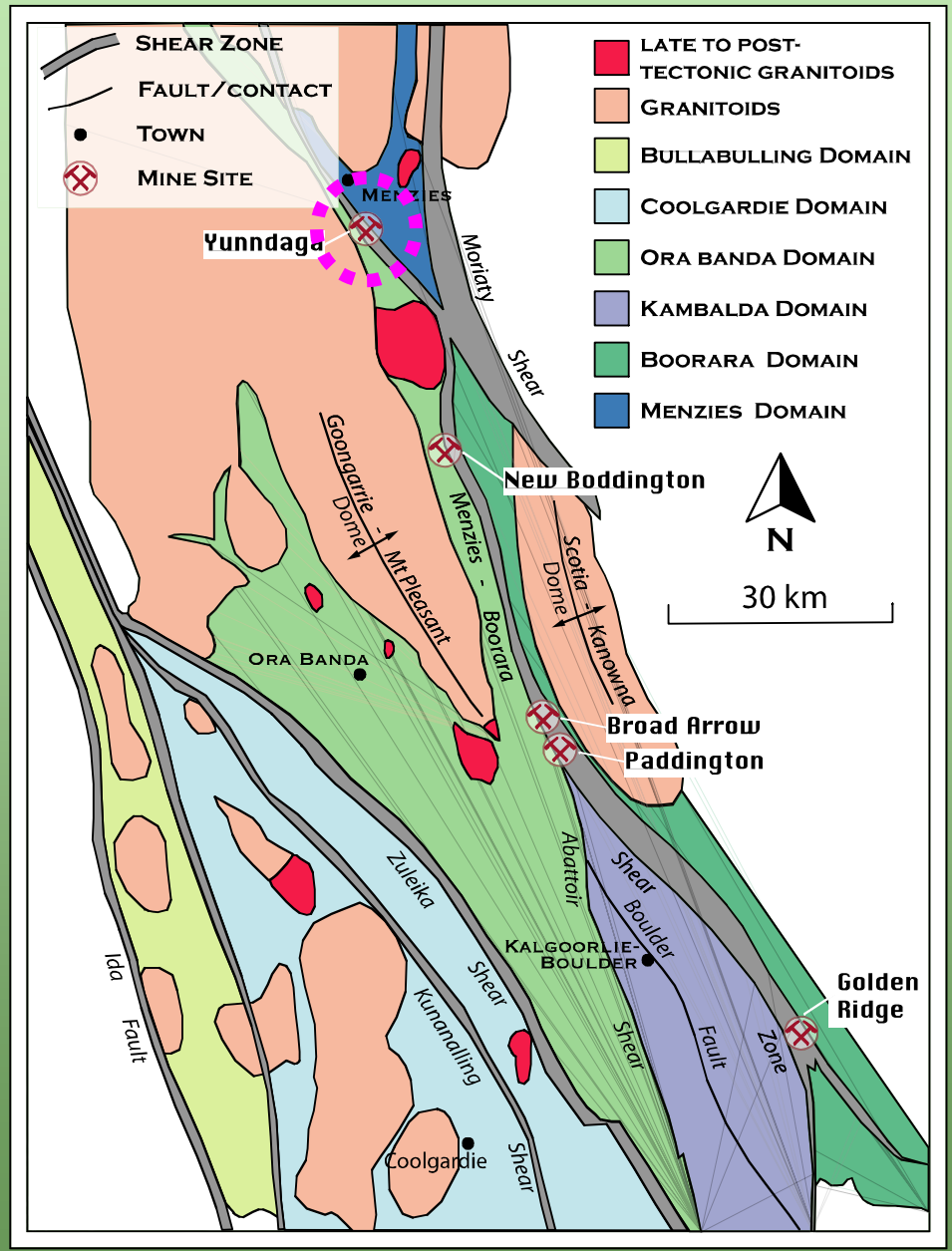
Major observations:

(1) Competence contrast

(2) Pre-shearing folds (D2) are preserved. Apparent lack of evidence for D3

(3) Many generations of fluid/veining events



After Witt (1993)

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Yunndaga

Total production:

0.460 Mt ore

- **1.3 t Au**

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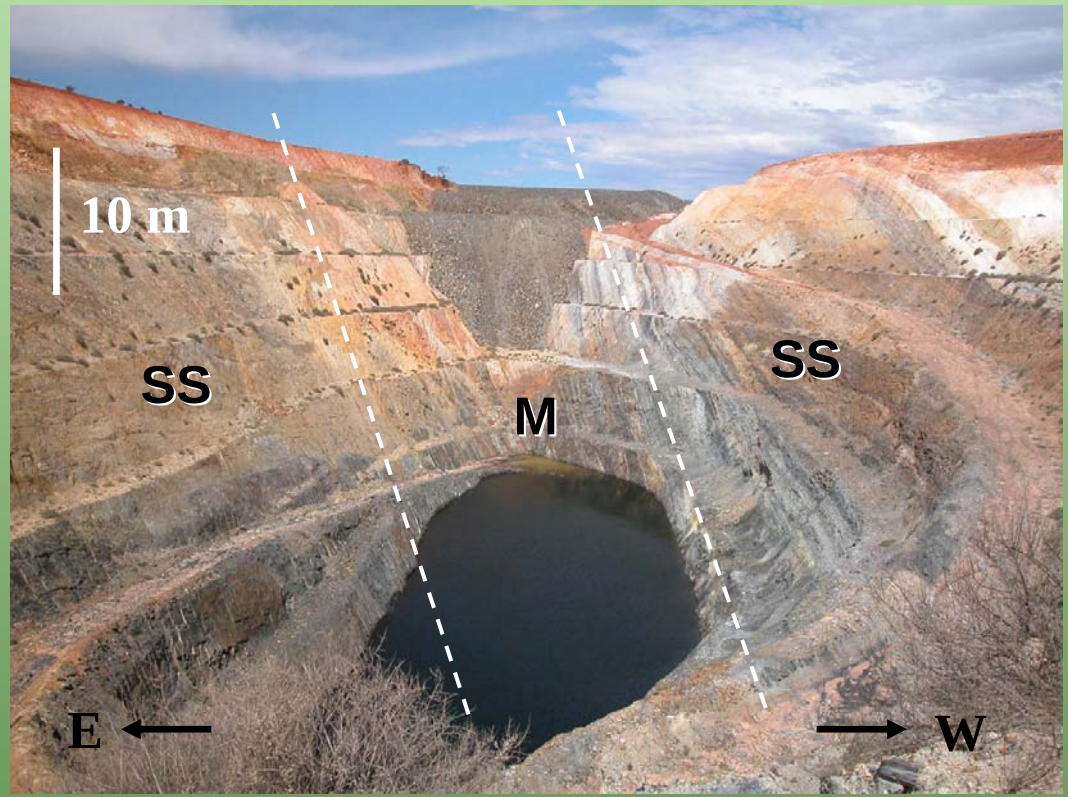
Work to date

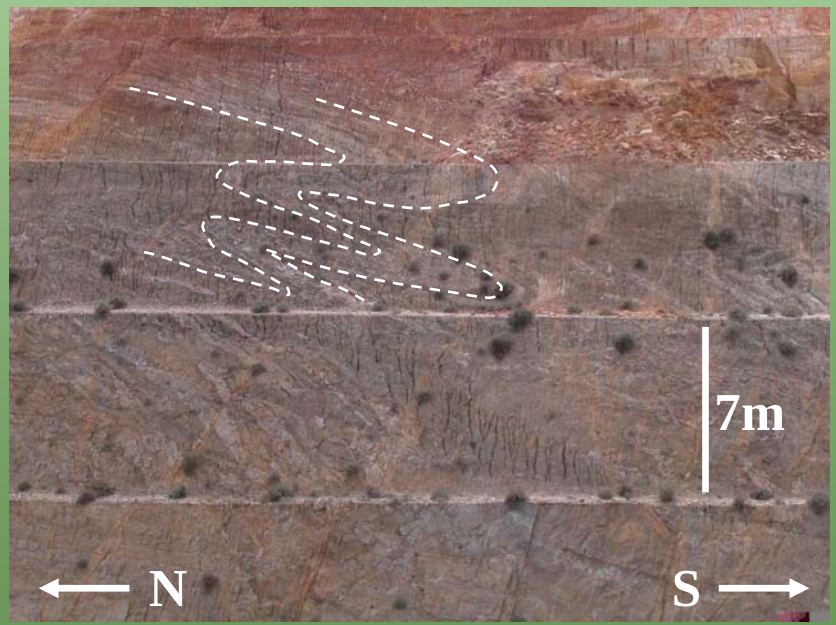


Yunndaga

Central mafic unit (M) in contact with interbedded shales/ sandstones (SS)

Yunndaga

- Tight, upright, NNW-oriented folds within bounding sedimentary units



Yunndaga - veining

Three vein generations

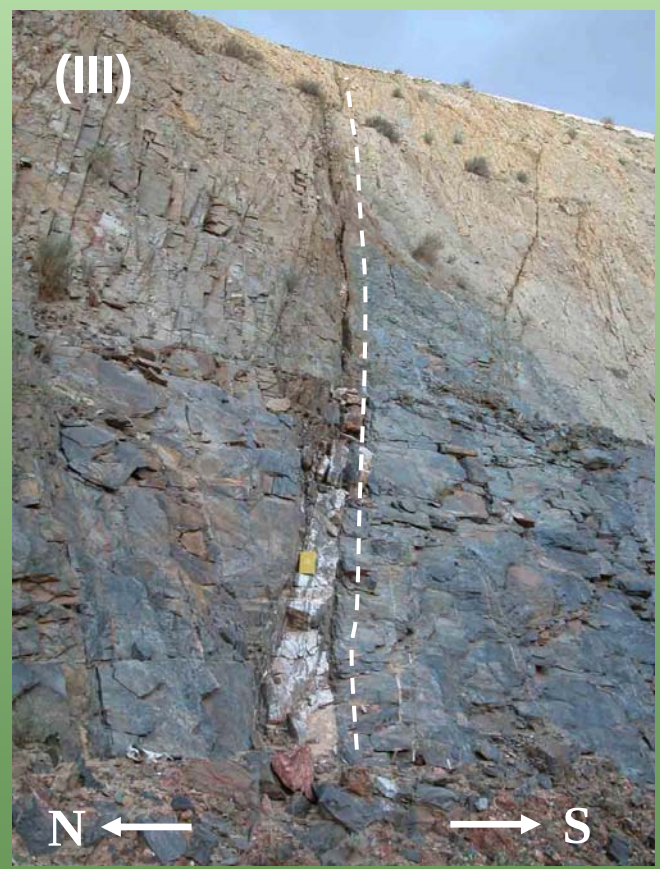
(I) Pre- to syn- folding (qz)

(II) Mineralised veins/brittle Structures (qz+carb+py+apy)

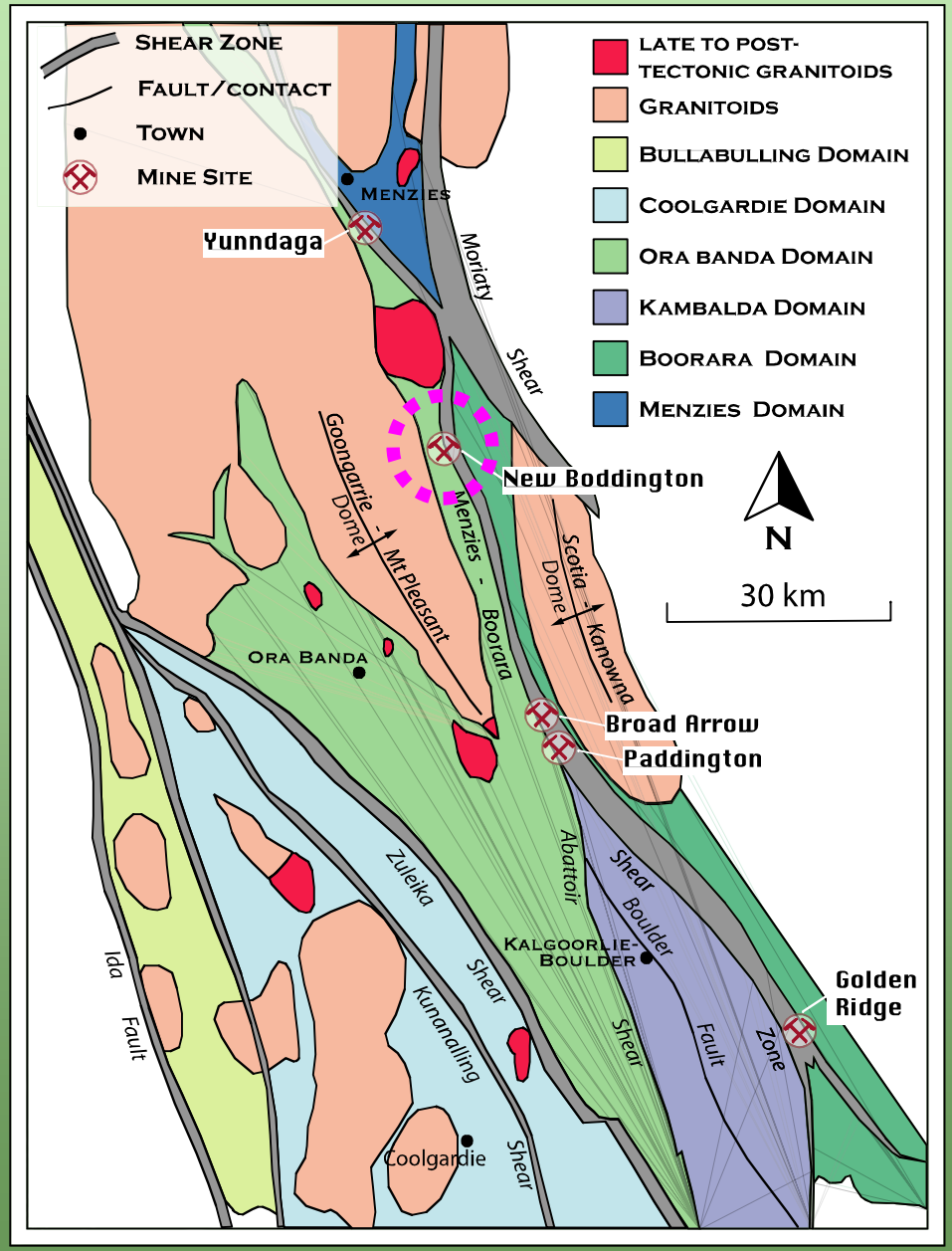
(III) Post-mineralisation Veins (qz)

Yunndaga - veining

(II) Mineralised veins (qz+carb+py+apy)/structures



(III) Late, sinistral faulting & associated veining (qz)



After Witt (1993)

New Boddington

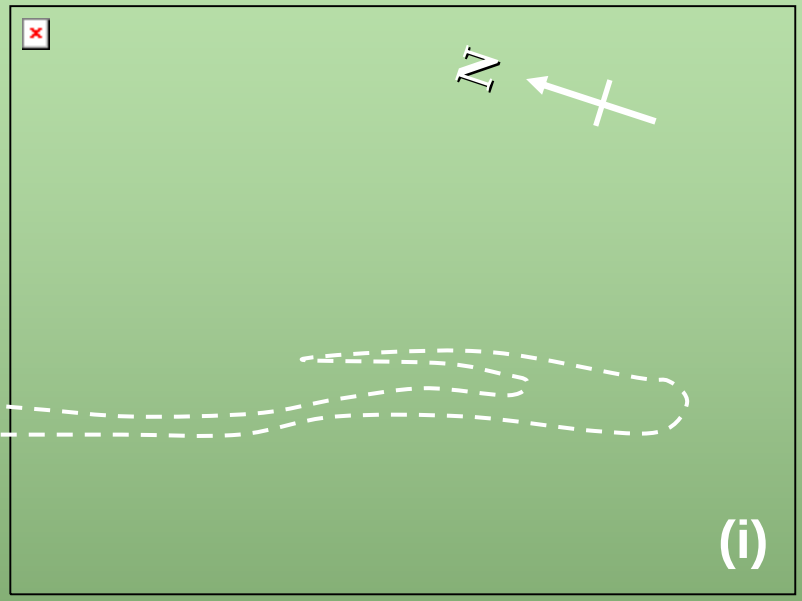
Total production:

- **0.41 t Au**

(i) Major shear planes

(ii) Interflow sedimentary unit

New Boddington



- **(i) folded, pre-/syn-deformation qtz veins (unmineralised)**
- **(ii) planar, mineralised (qz + py + apy) veins**

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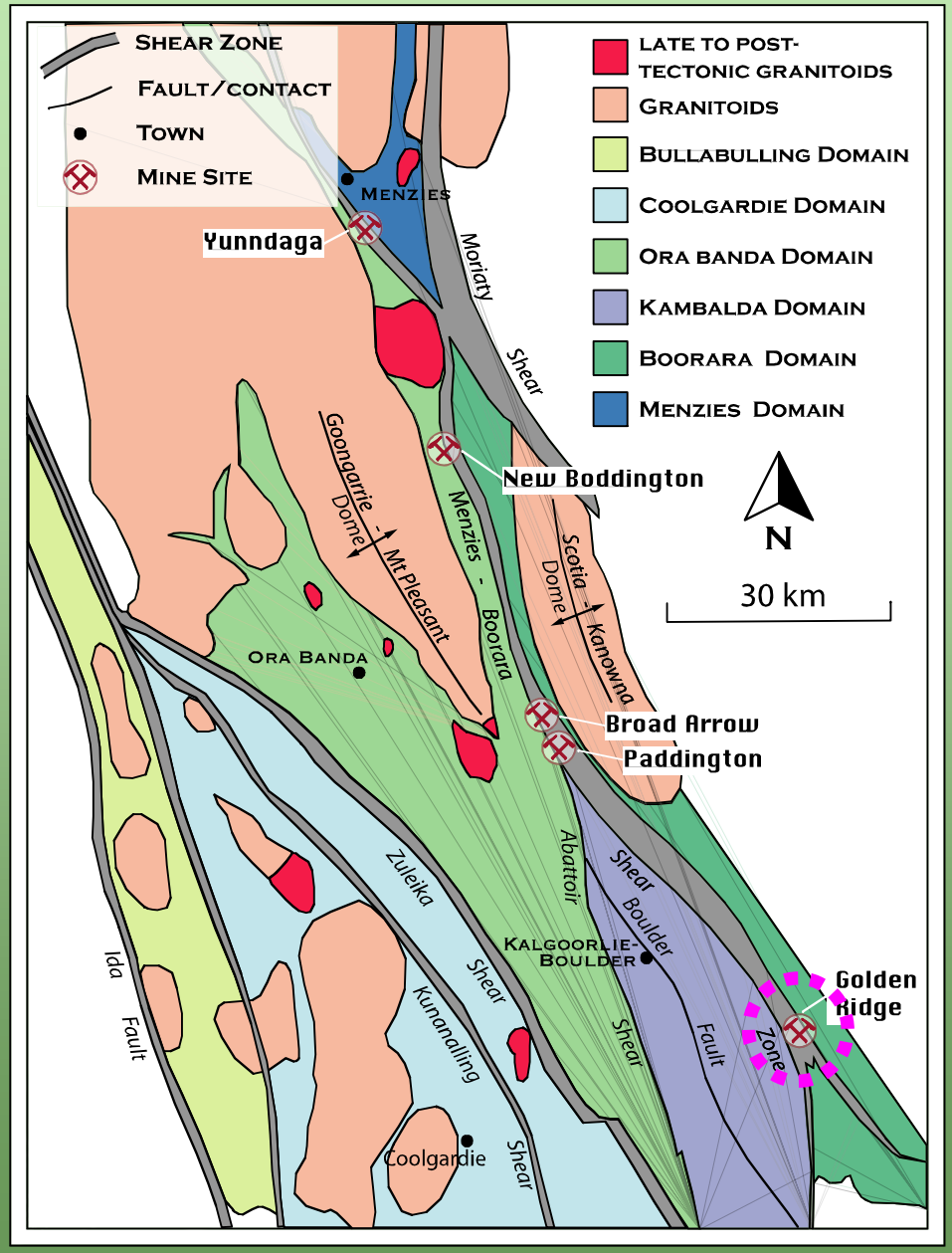
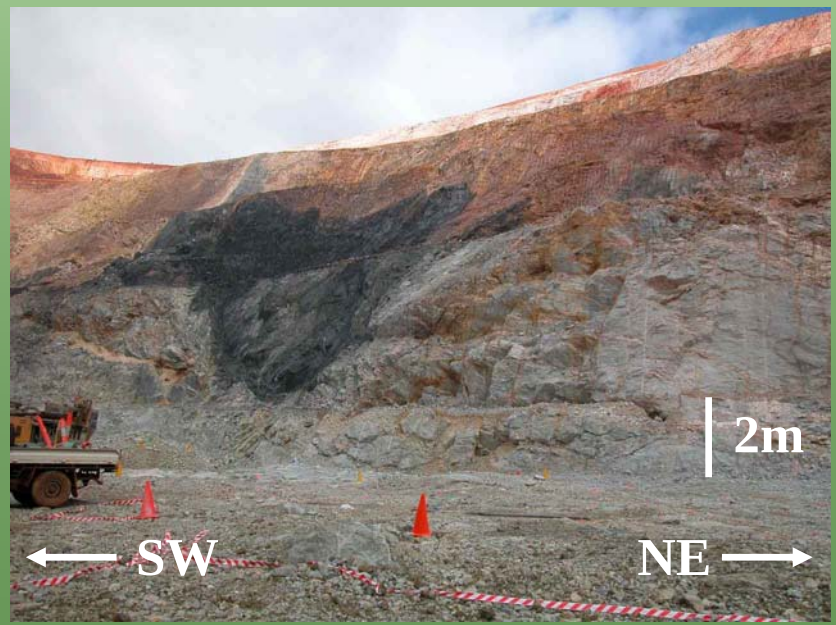
Golden Ridge

Production:

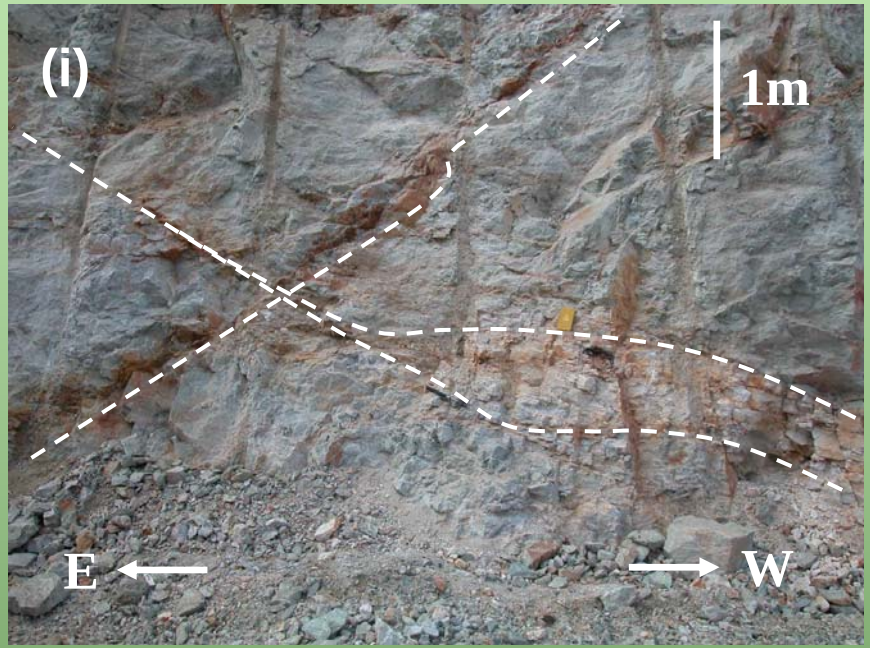
- 2.25 Mt ore
- 4.61 t Au
  - ➢ Currently being extended to ~ 7t Au





After Witt (1993)

Golden Ridge

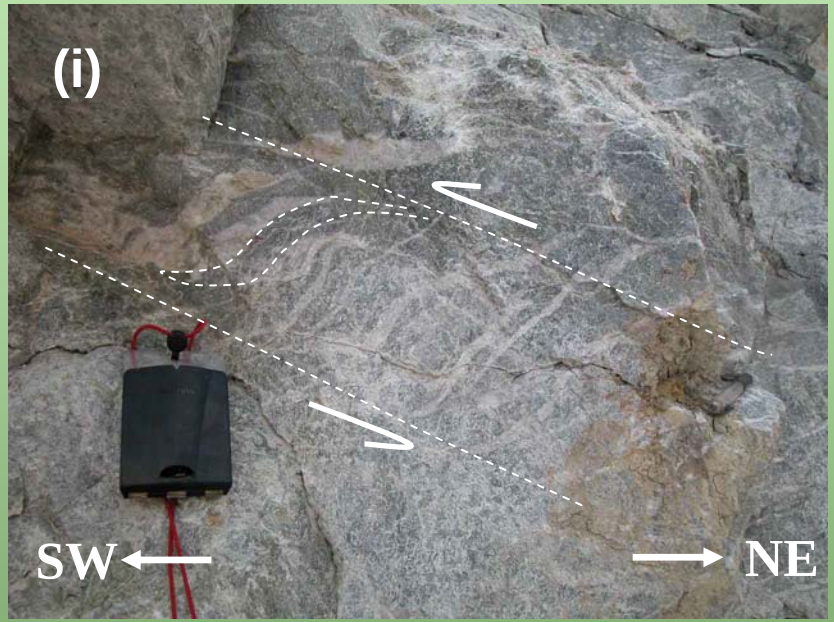


- **NNW-trending felsic porphyry**
- **Bound by ultramafic and sedimentary rocks**

Conjugate (i) and

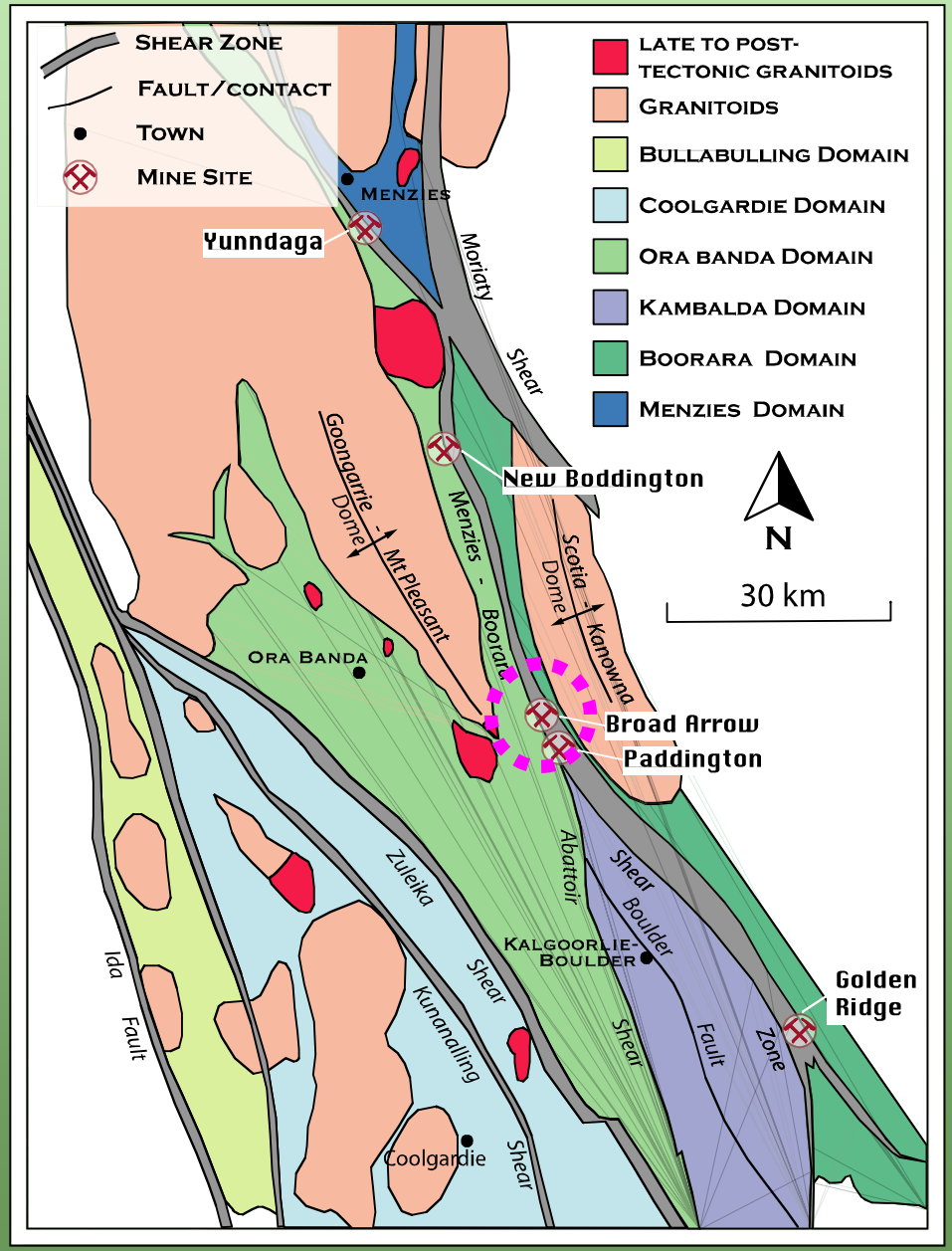
overprinting vein sets (ii)

Golden Ridge



(i) *En echelon* quartz veins

(ii) Carbonate veining within bounding ultramafic unit



After Witt (1993)

Broad Arrow

Production:

- **4 Mt ore**
- **12.9 t Au**

Broad Arrow

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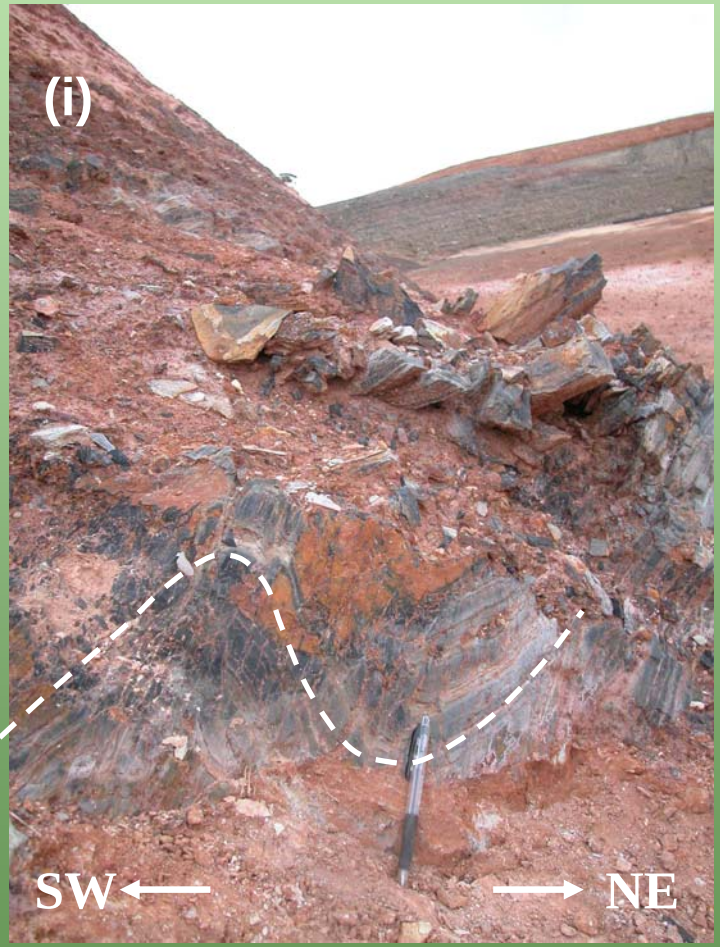
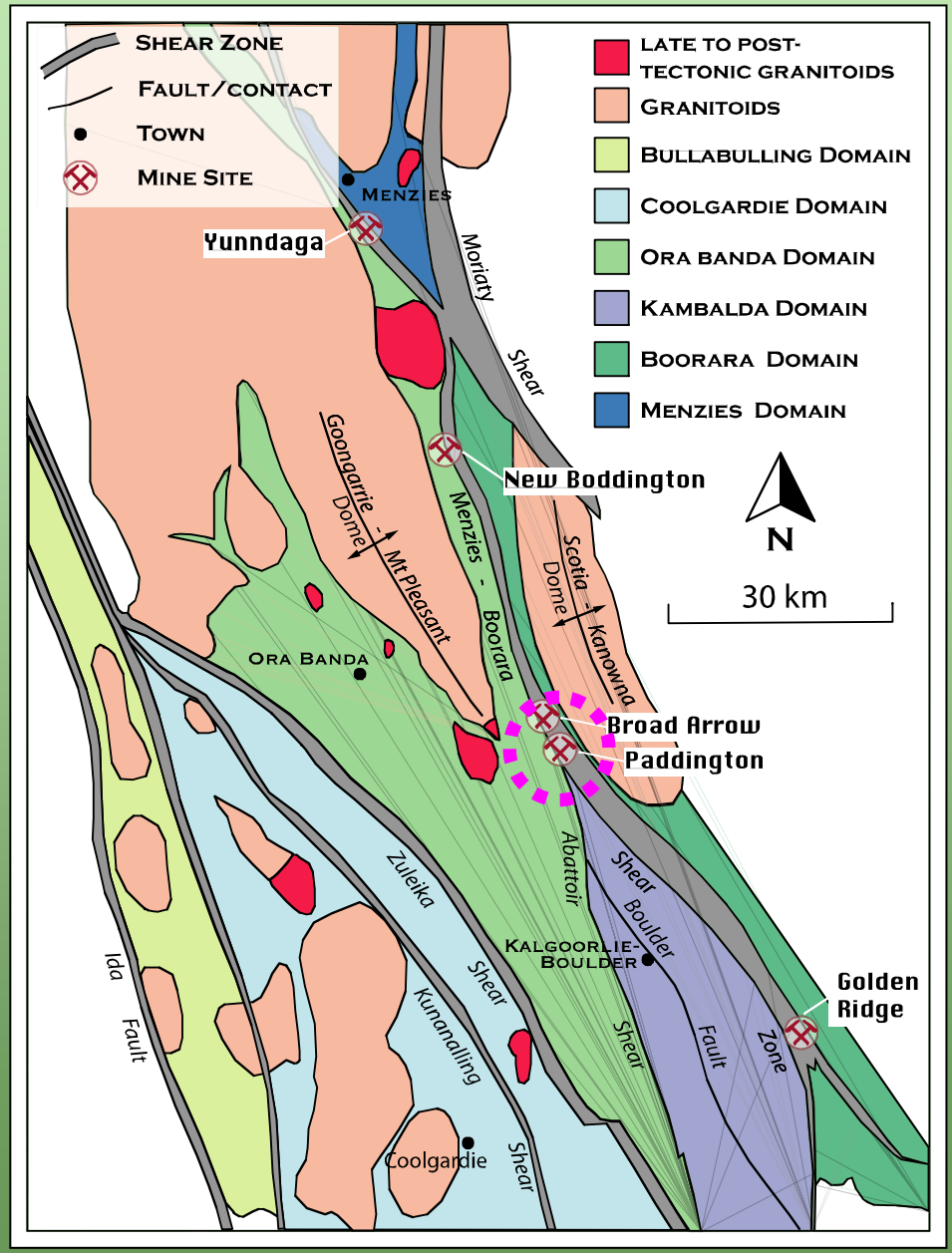
- **Gabbro (G) unit flanked by sheared shales (S) and sedimentary rocks (SR)**

Broad Arrow



- **(i) NNW-oriented, upright folds**
- **(ii) apy-py-qtz Au mineralisation**



After Witt (1993)

Paddington

Production:

- **55 Mt ore**
- **29 t Au**

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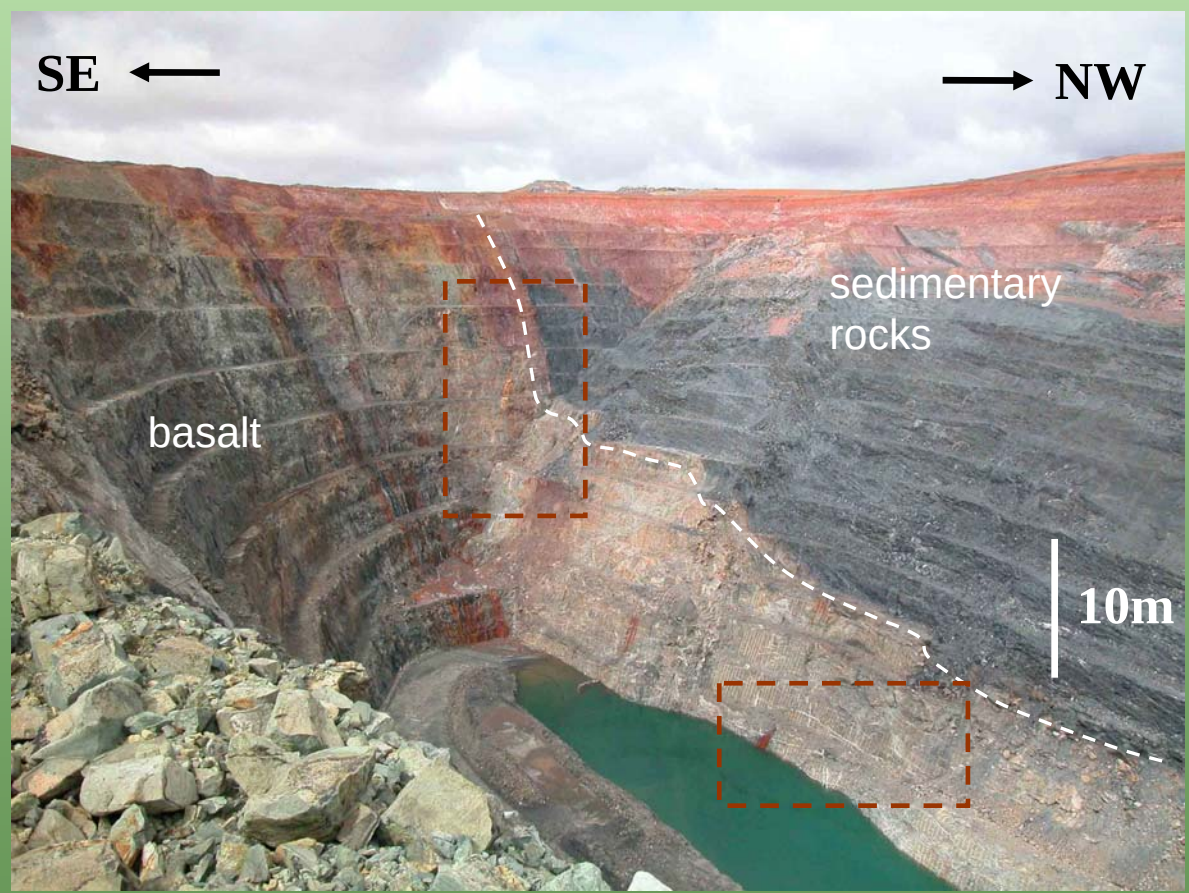
- **Basaltic and interbedded shales & sandstones**



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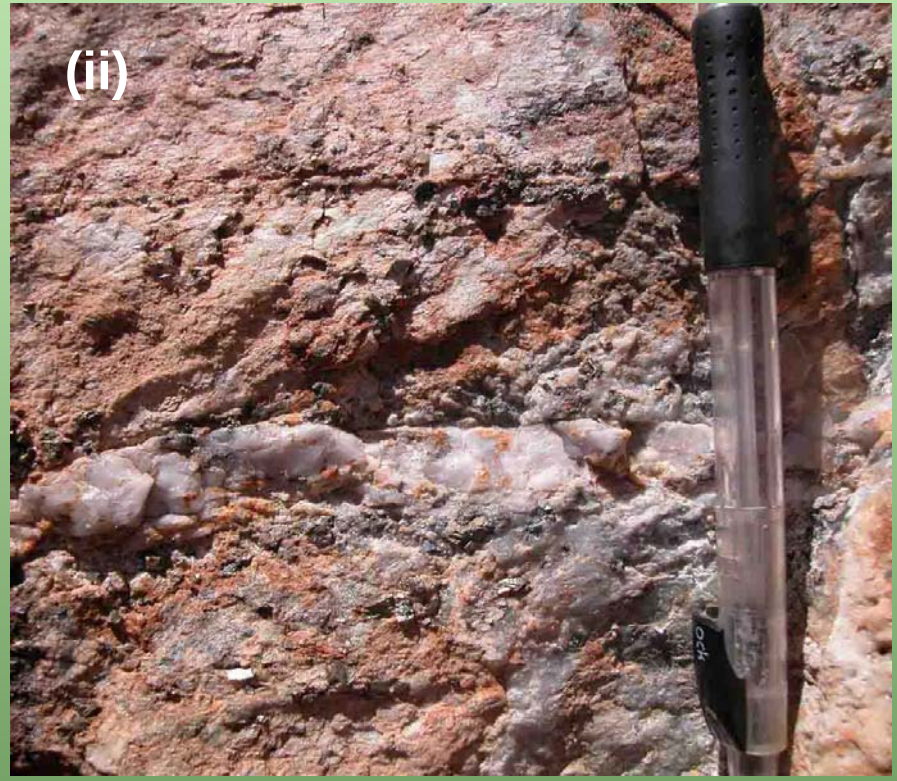
(i) ‘Laminated’ lode

(ii) ‘Ladder’ lode

Paddington

(i) ‘Laminated’ lode



(ii) ‘Ladder’ lode

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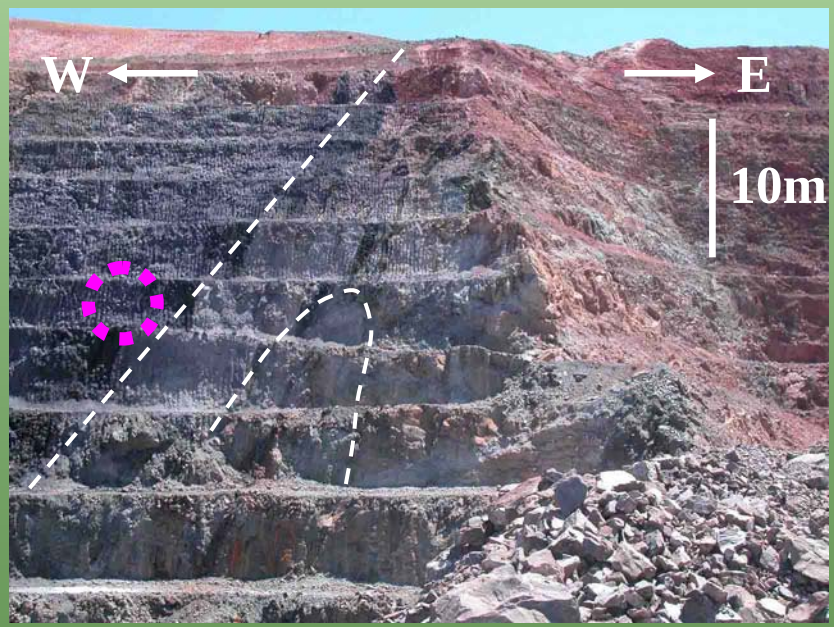
- **Syn-folding veins and ?post-folding veins**



In Summary

- **The importance of competency contrasts for Au mineralisation**

- **The D2 structures are preserved - apparent lack of evidence for regional D3 deformation within the MBSZ**

- **Many differing fluid infiltration events**

Comparison with BLF system

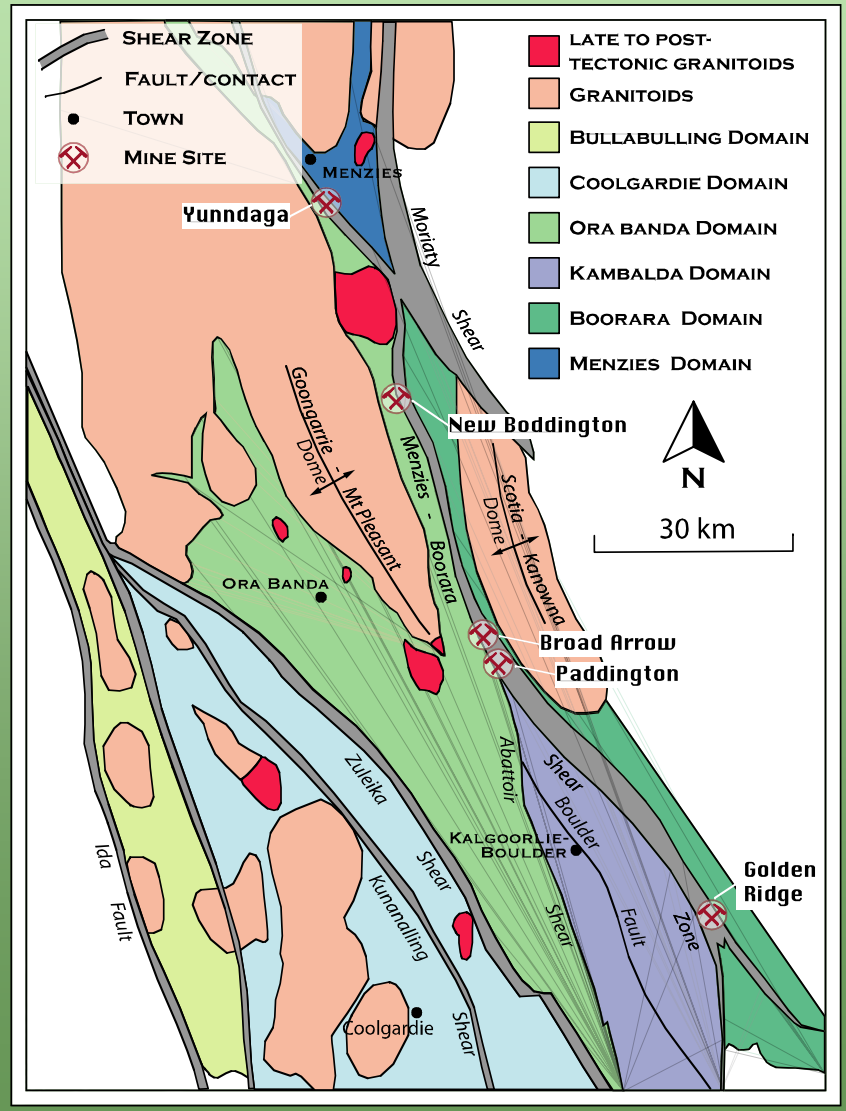
Similarities

- **NNW-striking**
- **Mineralisation interpreted as late (? D3-D4 event)**
- **Range of styles of mineralisation**
- **Lithologies, competence contrast**
- **Alteration (Fluid chemistry)**

Comparison with BLF system

Contrasts

- **Scale of shear zones primary SZ vs. secondary fault splay**
- **D3-type deformation observed**
- **Different kinematic evolution?**



Theories to test

Ongoing work will focus on:

- **Unmineralised sections of the MBSZ**
- **Significance of D2 folds and thrusts? - D3 regional-scale sinistral?**
- **Timing: Did the MBSZ have a different tectonic history?**
- **Is mineralisation not as focused as the Boulder - Lefroy Fault?**

The Architecture A1 Project

Habitat modelling of gold deposits in the Yilgarn Craton

Yilgarn Workshop; Perth, December 01, 2003

Archaean Au analysis

Summary of past year:

1. Analyse the MERIWA Yilgarn database (79 deposits)
   - many deposits with little data
   - sorted into groups of no data
   - unsuccessful by itself – no context
2. This database expanded into an Archaean Au database
   - 114 deposits, from granite-greenstone belts
   - 150+ characters
   - Mainly (97) Yilgarn deposits, some Canadian, others
3. Develop of Habitat mapping

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Habitat Modeling

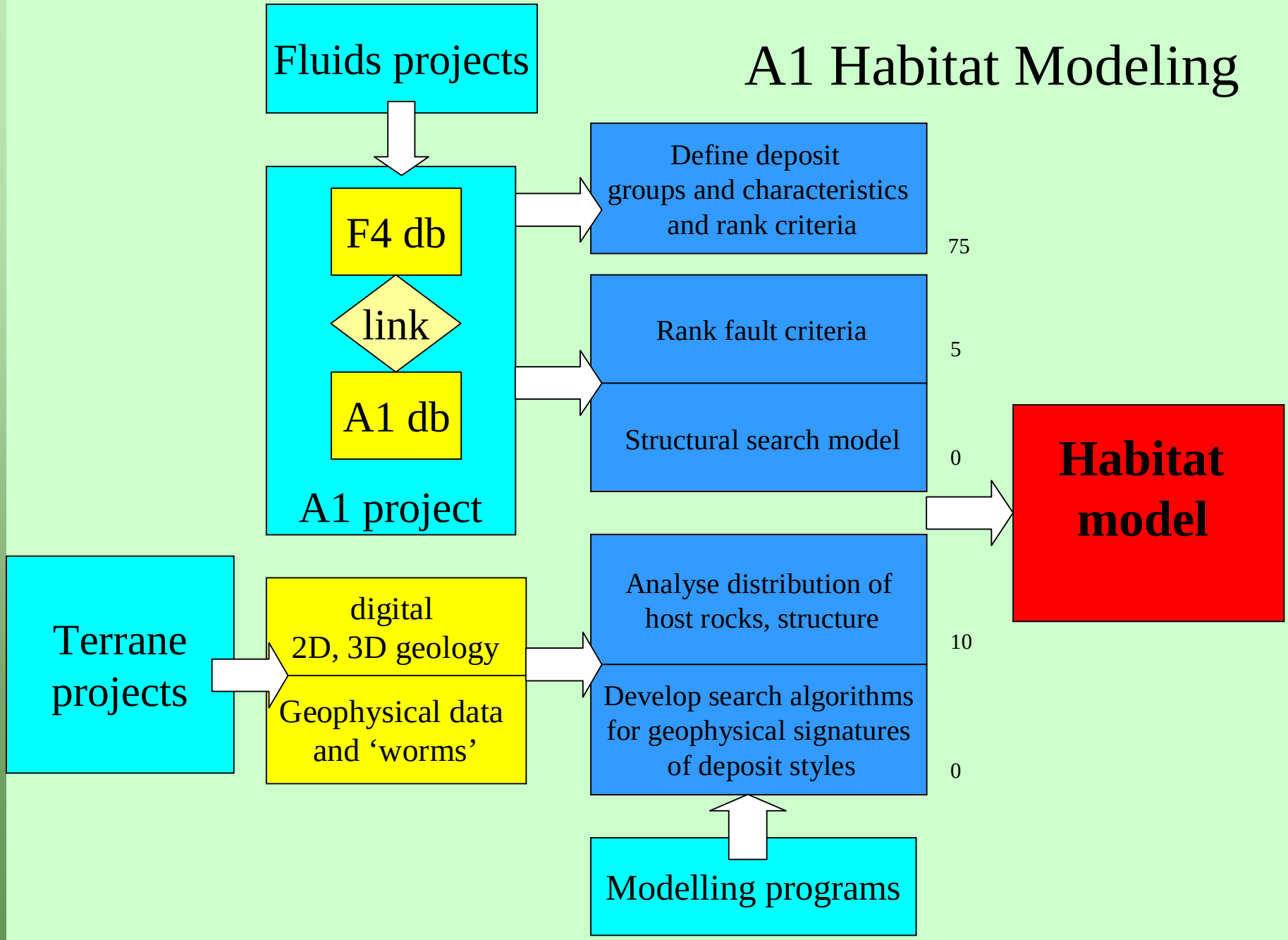
- From biology

- A statistical model that accounts for most of the variation in the distribution of a species (here a mineral deposit type). We don't know everything!

- Many factors taken into account

- Strong predictive capability

A1 Habitat Modeling



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Habitat mapping

For the Yilgarn, we need…

- to be able to characterise ('sort') all deposits
  (these groups have not been identified before)
- to analyse distribution of these mineral deposit groups against
  - Faults (length, intersections)
  - Worms (analysis of several variables [FCM])

Progress:

- Yilgarn Fault architecture being cleaned, merged
- Mineral occurrences (c. 10,000) merged from sources

Archaean Au analysis

Archaean Au database

- 114 deposits, 156-210 characters
- Some with very little data (eg Eureka)
- Character classes; fluid data, host rock, ore texture, ore and alteration mineralogy, ore and alteration chemistry
- Analyses by quite different software types: patn, phylip (similarity); PAUP, nona (genetic); snob, SOM (CSIRO clustering)

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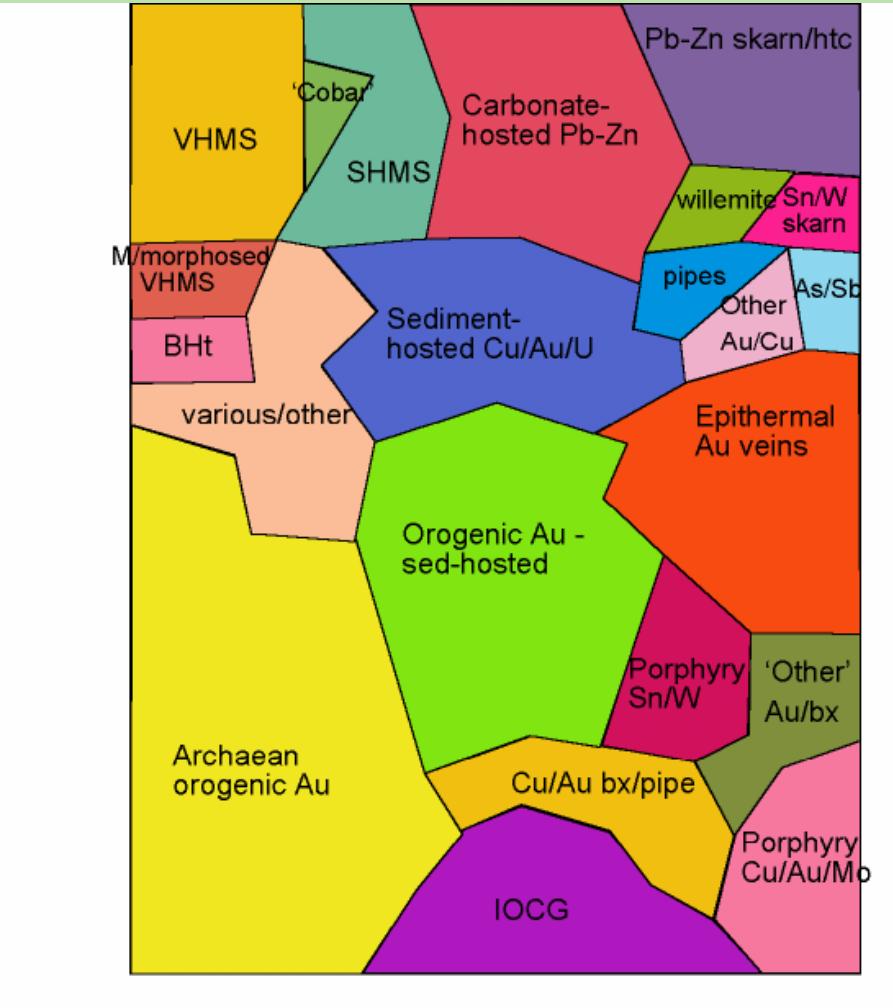
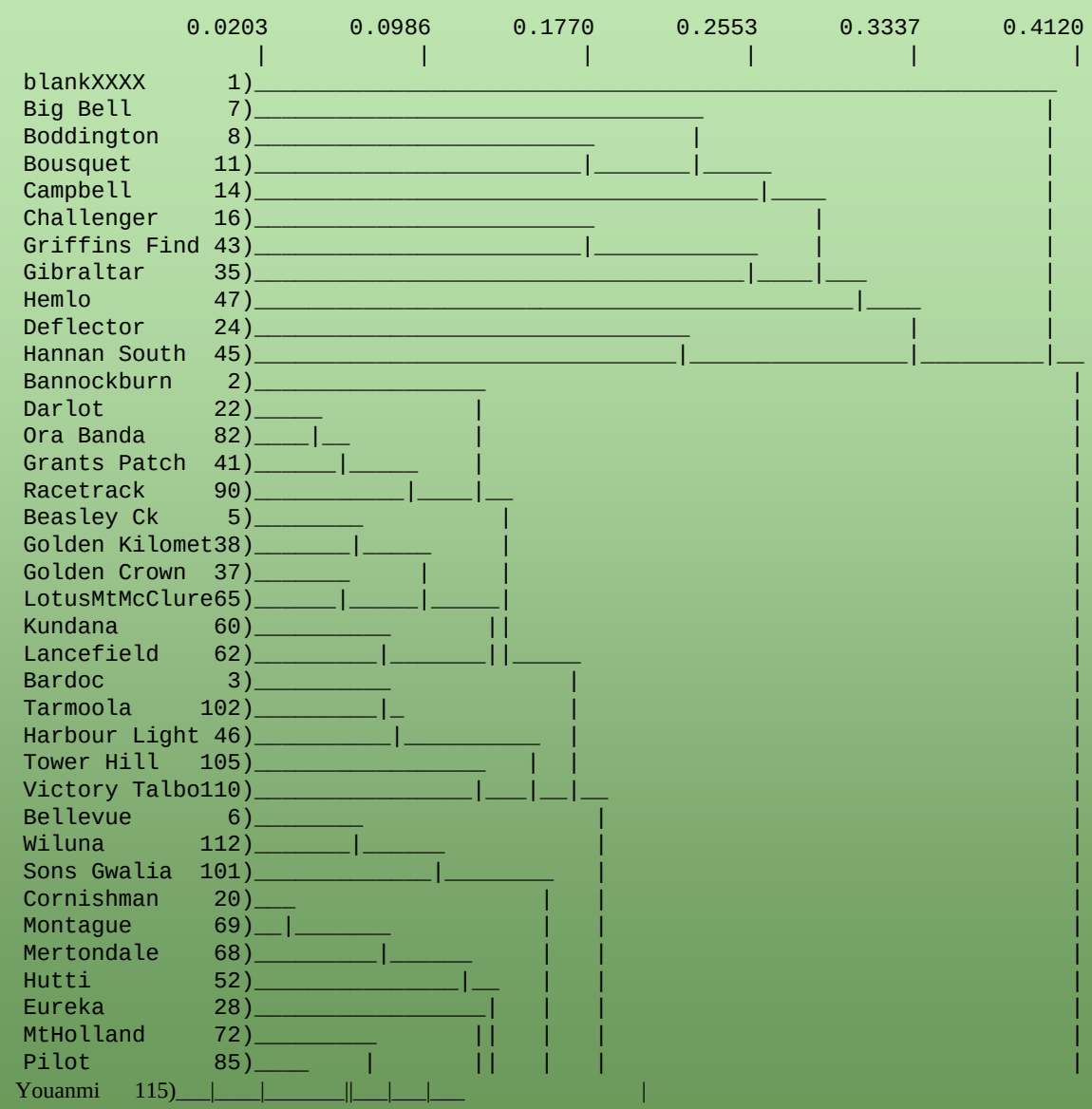


Context: simplified interpretation of SOM analysis of global database (>400 deposits) into classic ore deposit styles.



patn analysis (part)
114 Archaean
Au deposits.

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CSIRO SOM analysis

- Fraser and Dickson CSIRO E & M
- Clustering tool converts complex n-D data to 2-D image
- Can then divide into ‘x’ groups
    - Unknowns are one group
    - Some influence of lack of data

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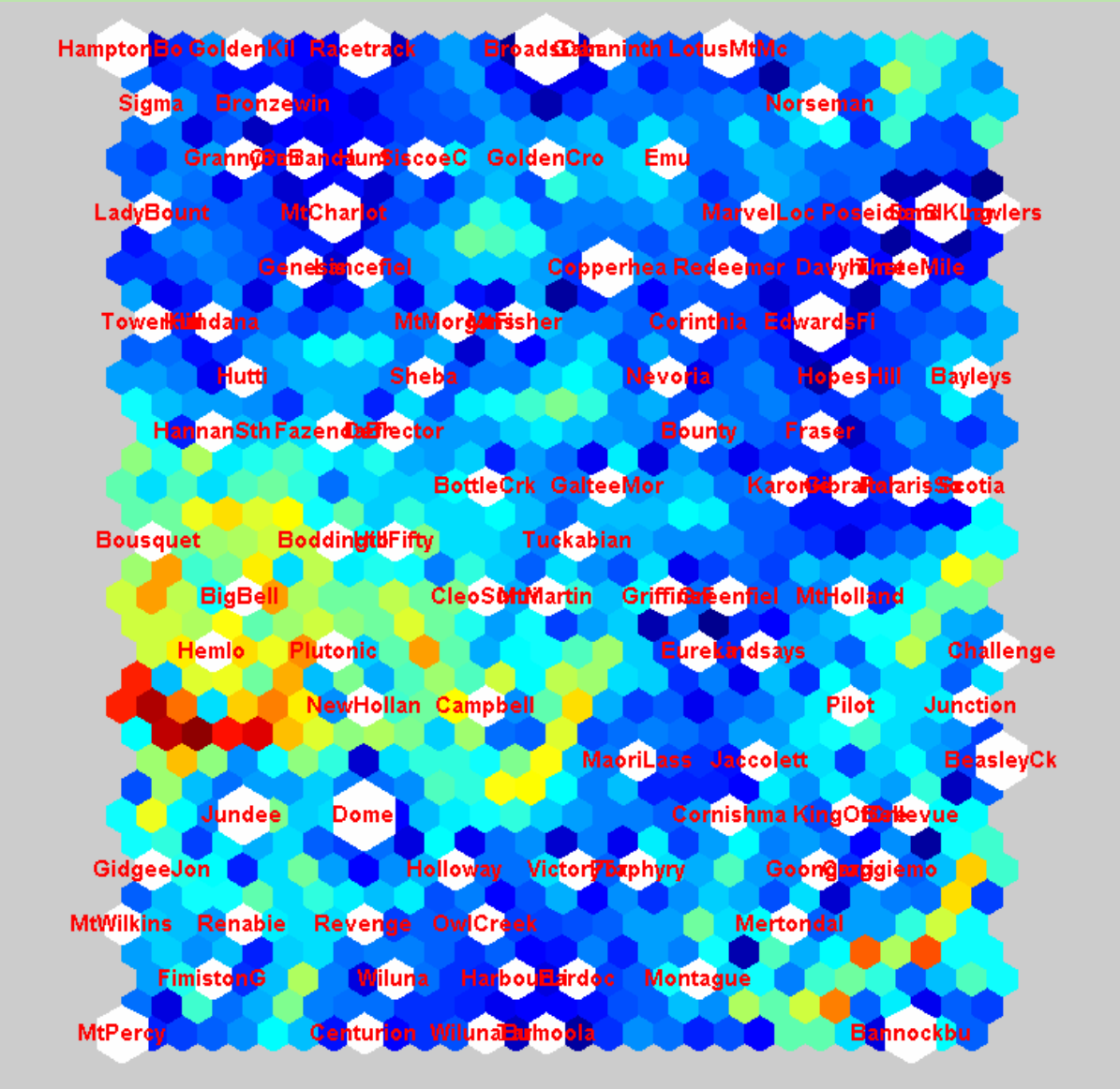

SOM analysis
112 Archaean
Au deposits
(by S. Fraser &
B. Dickson, CSIRO).
Groups lie in blue
areas separated by
higher colours.

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Archaean Au analysis

Despite quite different types of analysis ……

- Shows a number of consistent groups or clusters
- Groups have geological meaning, eg
  - Poor data
  - bif-hosted
  - low mm grade
  - high mm grade 1
  - high mm grade 2
- Groups have quite different Au endowment (blind test; no Au data

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Archaean Au analysis

Rationale for the groups

1 Data-poor group

2 Bif-hosted group

- different mineralogy and process (replacement)

3 Low and high metamorphic grade groups

- different mineralogy of ore and alteration
- various sub-groups based on host rock, alteration (albite)

4 High metamorphic grade group 2

- hosted by granite/porphyry
- abundant tourmaline
- possible influence of granite in ore deposition process?

Major groups and endowment

(all blind tests – no tonnage/grade data input)

1. SOM

SOM Group	Poor data	High mm grade 1	bif-hosted	High mm grade 2	Low mm grade
n	8	28	17	6	53
Average kg Au	5150	20188	25723	191083	78844

Major groups

2. Combined from all analyses

data poor/SOM	11	paup/nona	7	bif/patn/paup	12	patn_1/paup	9	lowgrade/S	48	highgr	26
BeasleyCreek	3192	CenturionB	2725	GalteeMore	707	BigBell	78200				
Bellevue	17550	SiscoeC	27500	MtFisher	1500	Boddington	102000				
Cornishman	4000	Renabie	37700	RandallsGroup	2666	Bousquet	23500				
Craggiemore	2350	Silidor	15000	Hill50	43200	Campbell	350800				
Goongarrie	4000	Sigma	110000	Tuckabianna	11865	Challenger	14820				
JaccolettiZone1	1630	Deflector	3060	Bounty	60300	GriffinsFind	2902				
KingOfCreation	3248	Renabie	37700	Nevoria	11448	Hemlo	670000				
MaoriLassTransvaal	500			Copperhead	25000	Gibraltar	3500				
Mertondale	7500			CleoSunrise	57600	Plutonic	257300				
Pilot	924			MtMorgansWestrali	28800						
Eureka	500			Corinthia	2500						
				MtMartin	8329						
SUM	45394		652575		253915		1503022		3724158		707342
n	11		7		12		9		48		24
Average	**4127**		**93225**		**21160**		**167002**		**77587**		**29473**
SD	4891		179815		21866		224852		230565		39615

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Summary

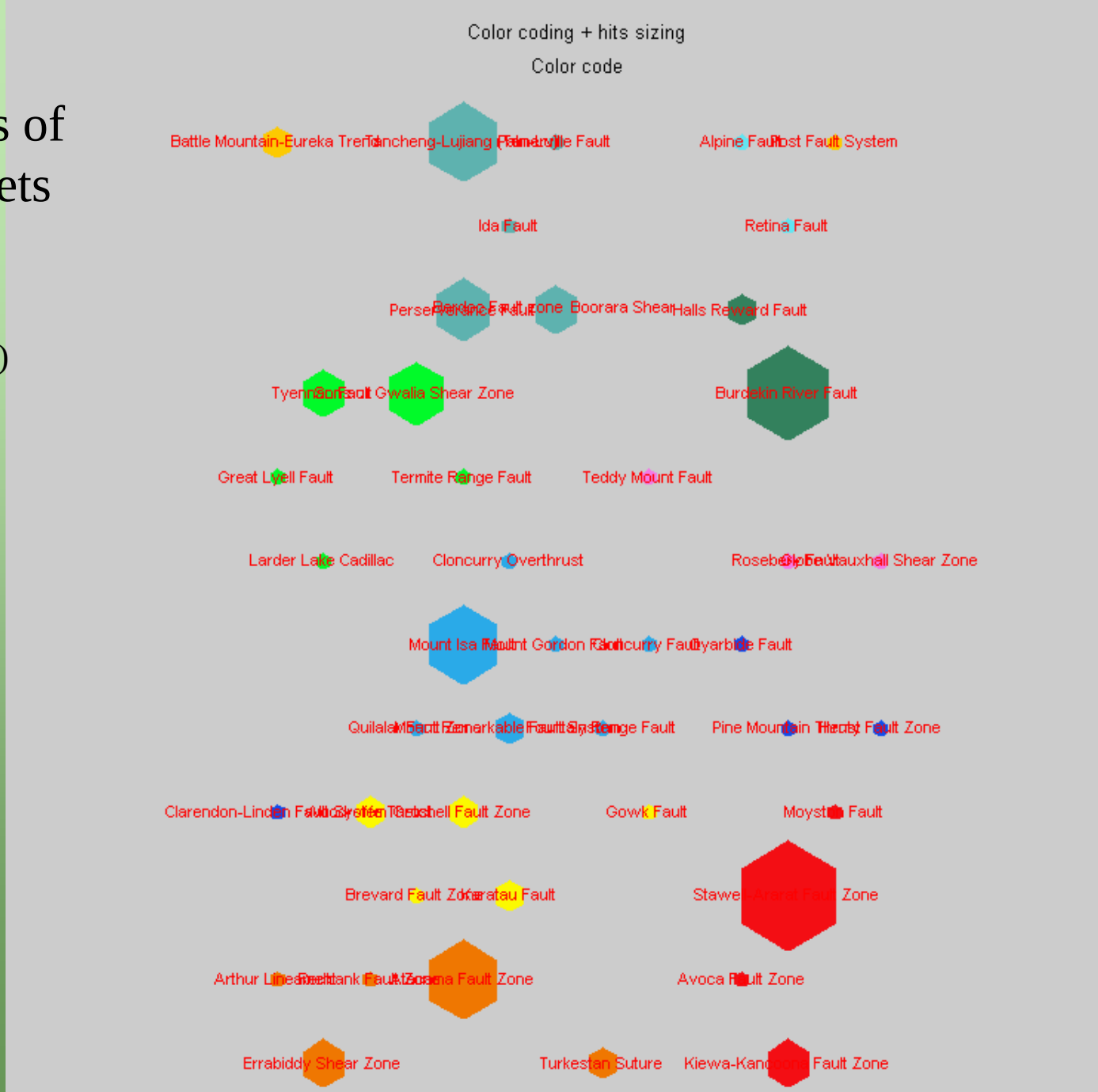
Data-driven analysis show….

- several distinct groups;
  - some logical and geological
  - 1 or 2 'odd' and with anomalous endowment

The different groups provide an opportunity for habitat mapping

SOM Analysis of Tectonic Targets Database

Steve Fraser (CSIRO)



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What to do next?

- We need
  - Feedback
  - Direction
  - Deposits in the database (Twiki A1 from next week)
  - Faults input (web-enabled entry form on Twiki)

- What can we do for you?