A multi-disciplinary study of the tectono-metallogenic evolution of the Tasman Fold Belt System in NE Queensland, Australia.

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Project supervision

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Project collaboration (and acknowledgements)

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Bruce Goleby; Richard Blewett (Geoscience Australia)

Graham Teale (Teales & Associates Ltd, Adelaide)

Chris Roberts, John Kelly (Republic Gold Ltd)

Barry Murphy (University of Melbourne)

John Webb (LaTrobe University)

Paul Donchak (GS QLD)

John Nethery (Nedex Ltd, Chillagoe)

Architecture (A1) project

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

Why are some faults mineralised and some barren: define set of critical parameters to reduce risk in predictive mineral discovery.

This project specifically:

- **Input from low data-density key areas**
- **Understanding of fault nature and mineral potential**
- **Application of results to similar systems elsewhere (pmd!)**

Architecture (A1) project

Tectonic Targets
& Deposits Database

Key Area Studies
(Mt Isa, Yilgarn, HBR, Lachlan)

database
criteria

validate

input

geology, structure, tectonics,
geochronology, geochemistry,
geophysics (seismics, worming)

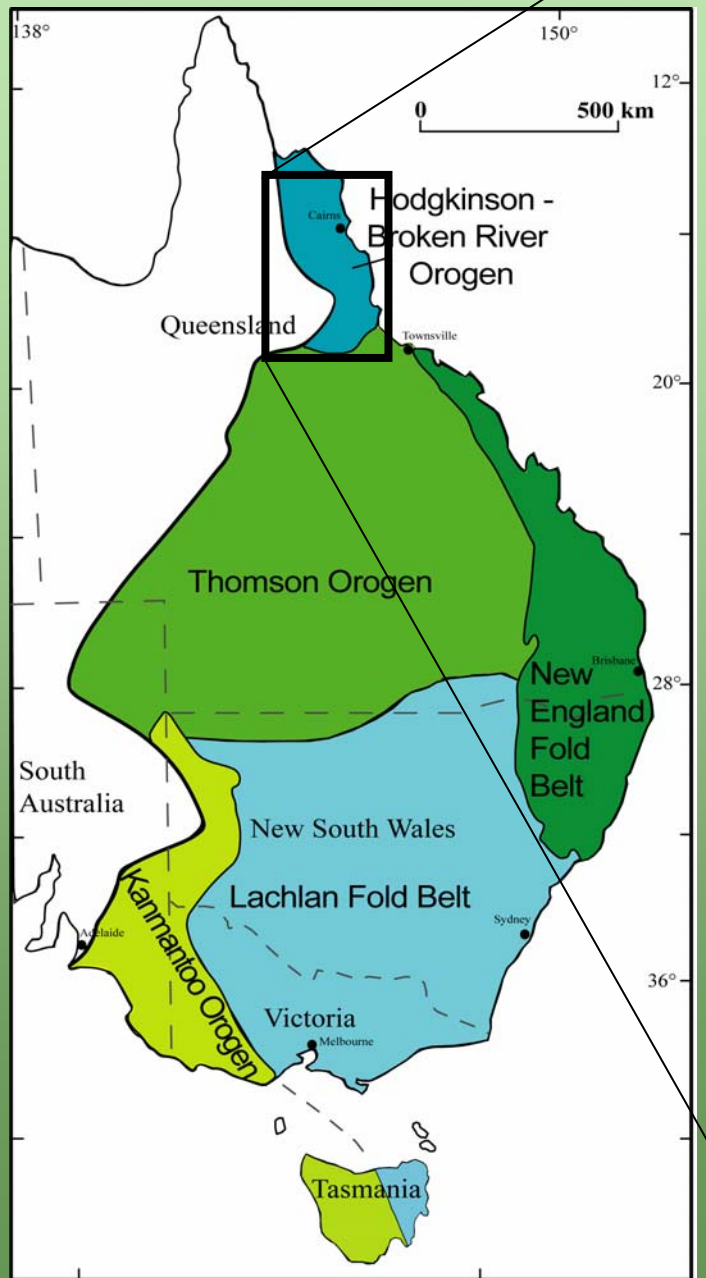
+ literature
pmd*CRC projects!

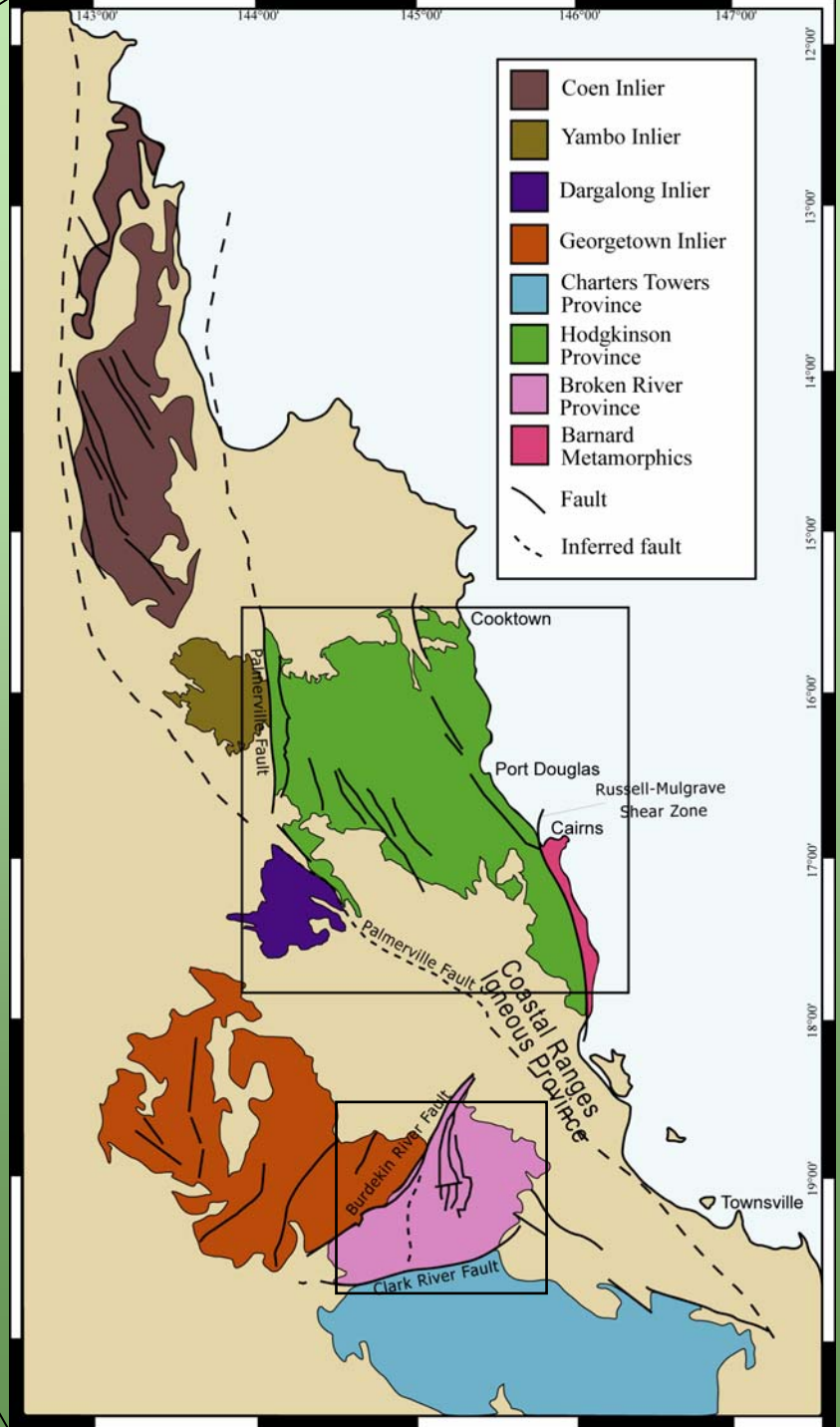
Process Understanding
(critical parameters)

Modeling Scenarios
(numerical, habitat)

Application to Industry
targeting at reduced risk

Study area





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Project setup:

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Tectono-metallogenic evolution

Geology

- Structural mapping
- Metallogenesis
- Absolute dating

Across all scales

Geochemistry

- Understand tectonic setting
- deposit-scale alteration

Geophysics

- Interpret available datasets
- Fault modeling
- Gravity / magnetics worming

Project aims and deliverables

Aim: Understand tectonic evolution of and the significance of mineralising episodes in the northern Tasman Fold Belt System

through:

- **Comparison of structural and metallogenic relationships in the Hodgkinson and Broken River Province on micro- to macro-scale**
- **Temporal constraints on gold mineralisation and deformation events in NE Queensland giving insight into parameters that control endowment**
- **Geophysical modeling and geochemical analyses**

Multi-disciplinary project – case studies

1. **Metallogenesis of gold deposits in the Amanda Bel Goldfield, Broken River Province**
   - ***controls on gold mineralisation***
   - ***predictive mineral discovery***

2. **Geophysical modeling of the Palmerville Fault**
   - ***tectonic evolution***
   - ***significance to gold mineralisation***

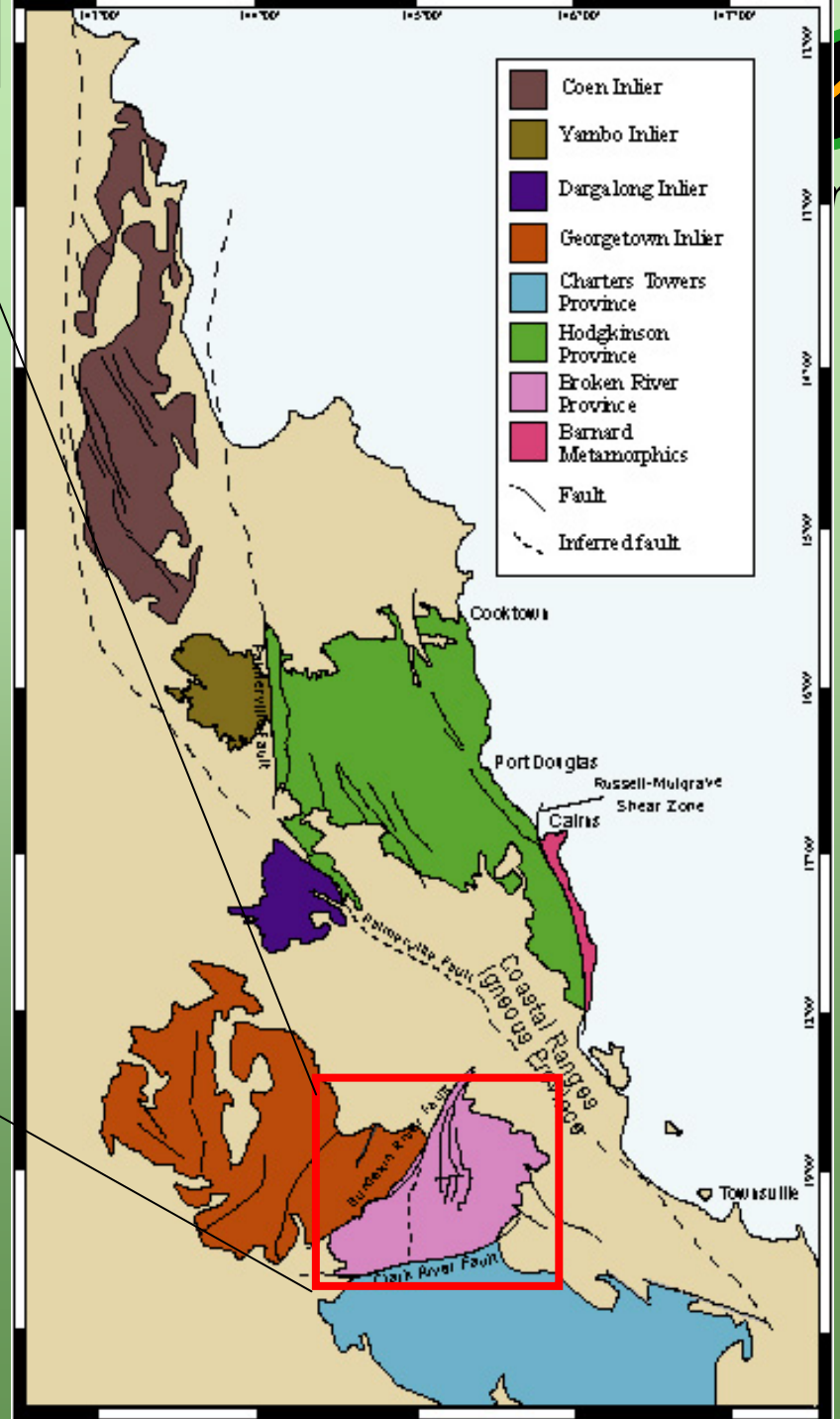
3. **Basalt geochemistry**
   - ***key to tectonic setting of the Hodgkinson Province***

4. **Metallogenesis of gold deposits in the Northcote District, Hodgkinson Province**

1. Amanda Bel Goldfield

Broken River Province

- Production of approx. 3 tonnes of gold with little alluvial gold present
- Deposits and prospects occur in a sequence that ranges from Ordovician to Carboniferous
- Metamorphic grade ranges from sub-greenschist to greenschist



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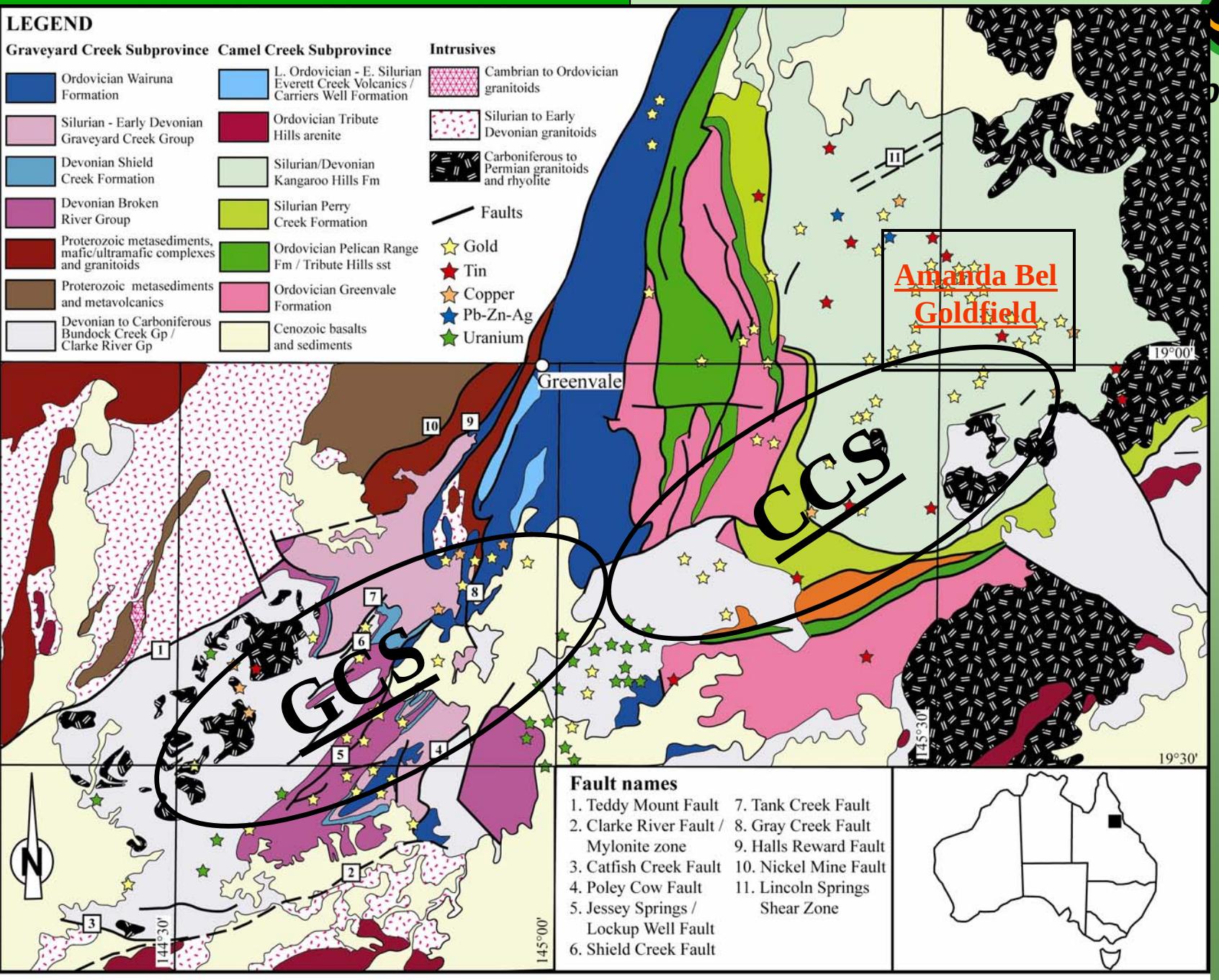

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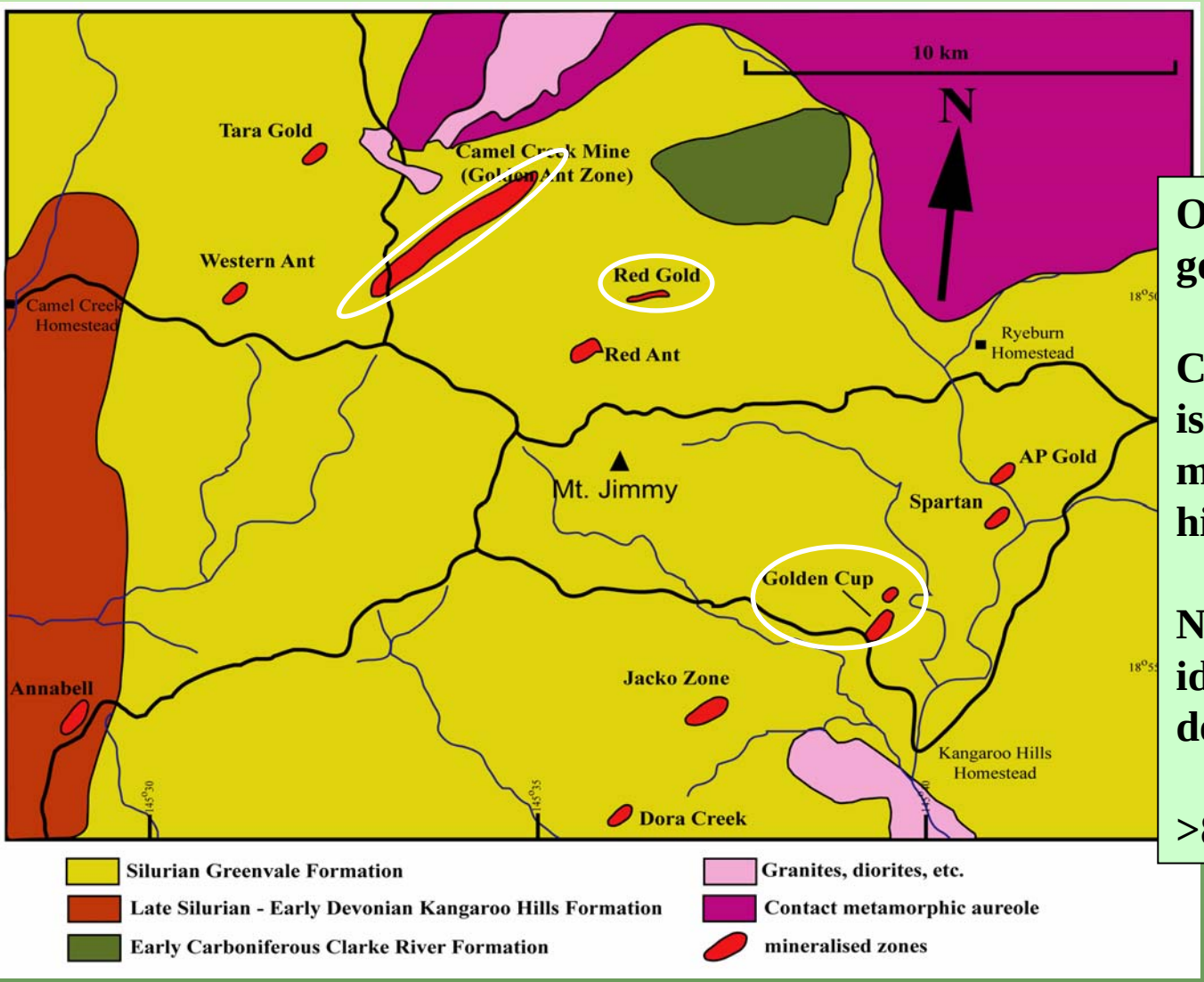

Overall NE-trend in gold deposits

Competency contrast is a major control on mineralisation (structurally higher)

No large-scale structures identified associated with deposits

>80,000 oz Au

Camel Creek deposit

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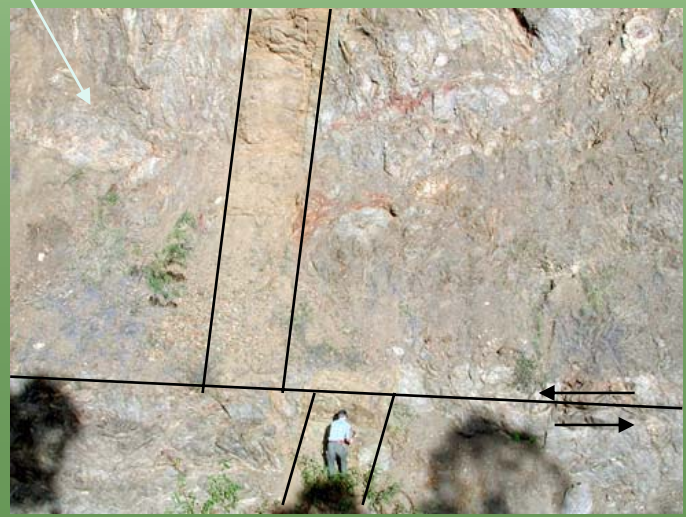
Barren quartz vein along D_3 thrust plane

Bedding-parallel quartz veins in refolded F_1-fold



Mafic dyke offset by fault

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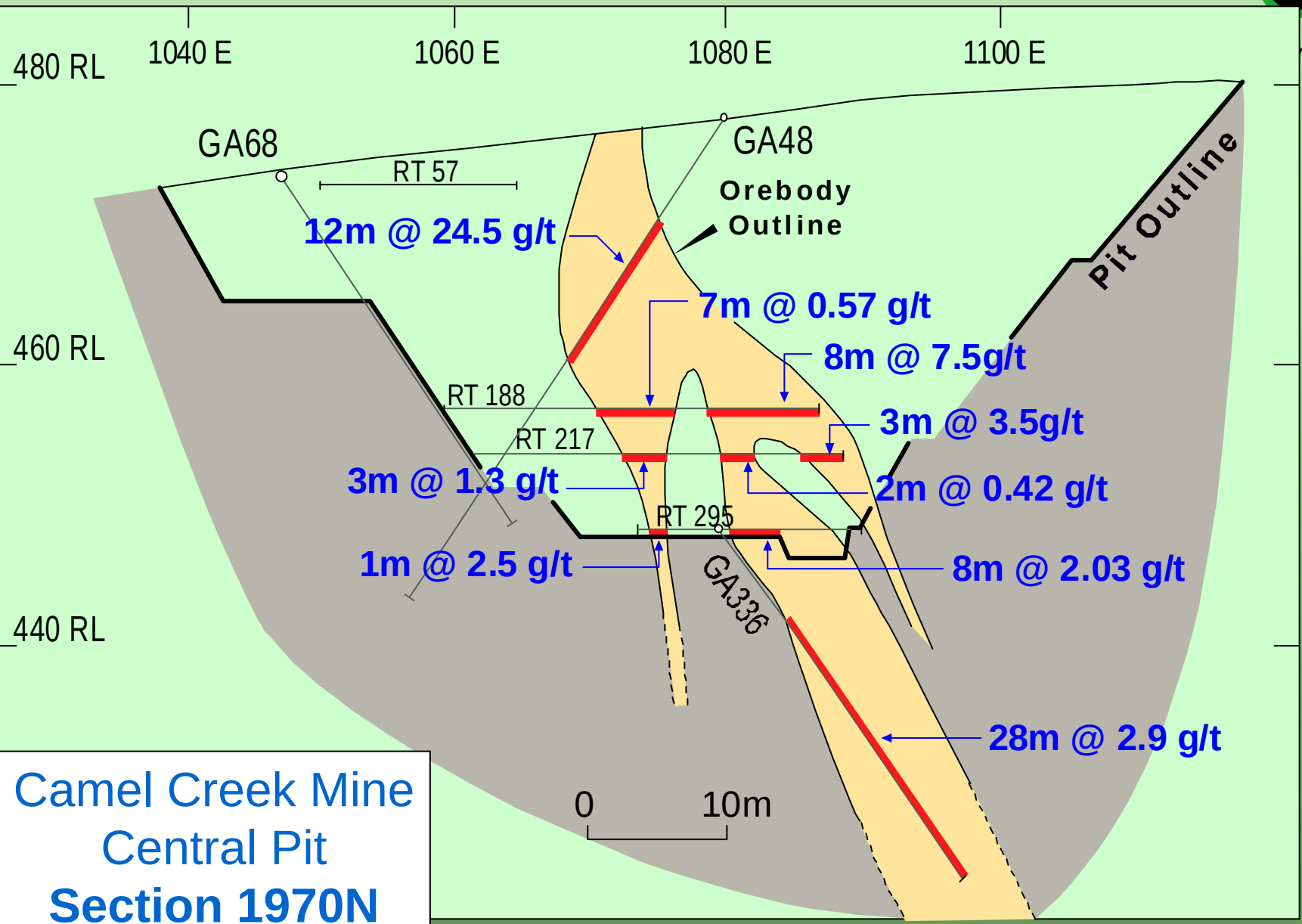
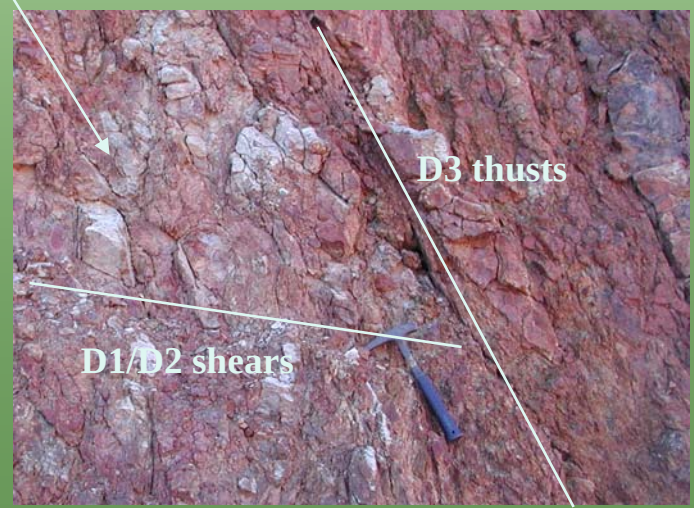


Camel Creek Mine
Central Pit
Section 1970N
(looking grid north)

Red Gold deposit

Mineralised quartz vein in D_2-shear

Slightly deformed syn-D_3 planar quartz veins



Relationship between D_1/D_2-shear structures and D_3-thrusts

Golden Cup deposit

Steeply dipping NE-trending shear planes associated with D_2 mineralisation

En-echelon quartz-carbonate breccia veins related to D_4

SW-dipping thrust faults and associated D3 quartz veins

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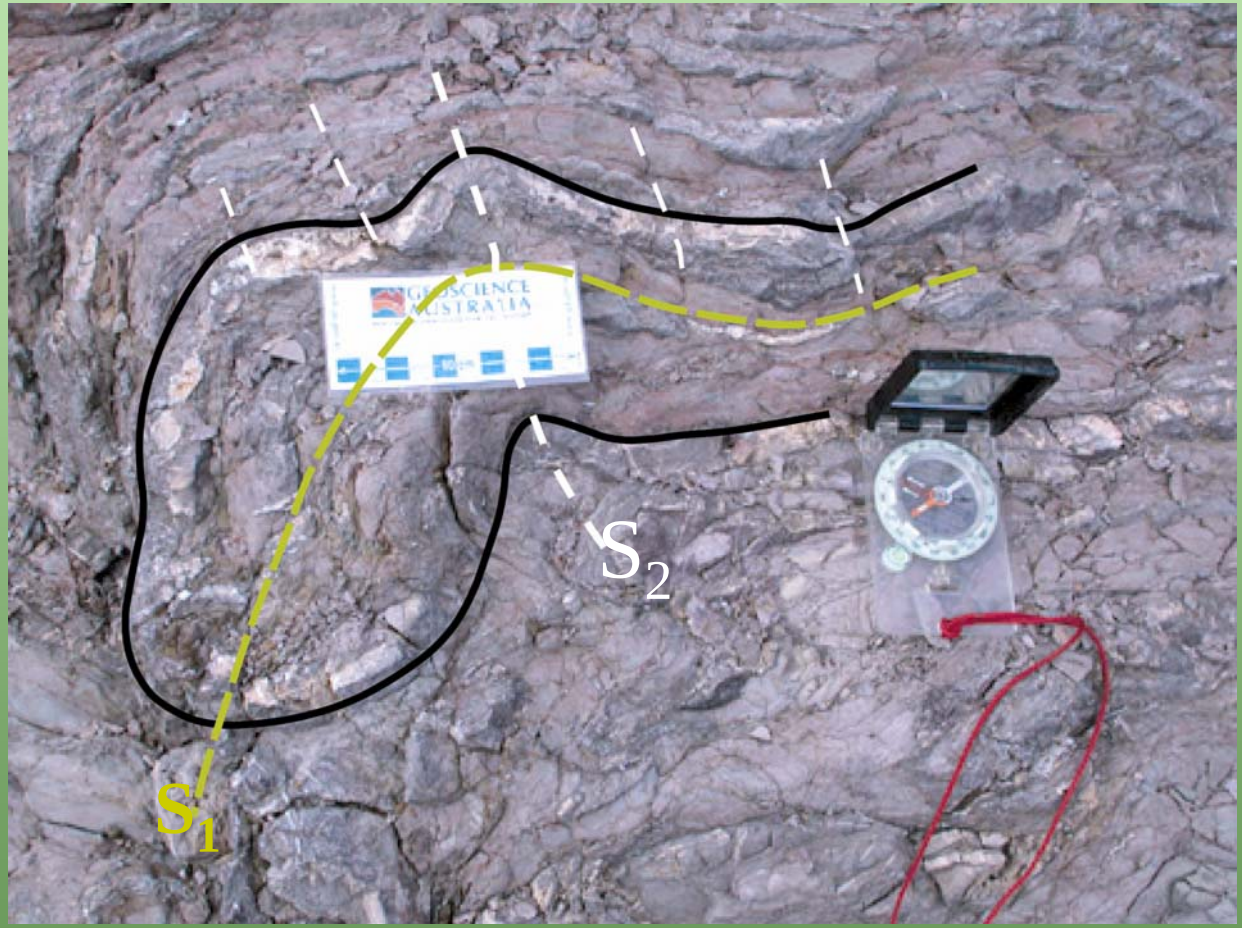
Structural framework

At least 3 deformation phases



Recumbent F_1-fold overprinted by NE-SW trending S_2 foliation co-axial to S_1 (Camel Creek deposit)

Quartz-filled D_3 reverse fault (Camel Creek deposit)

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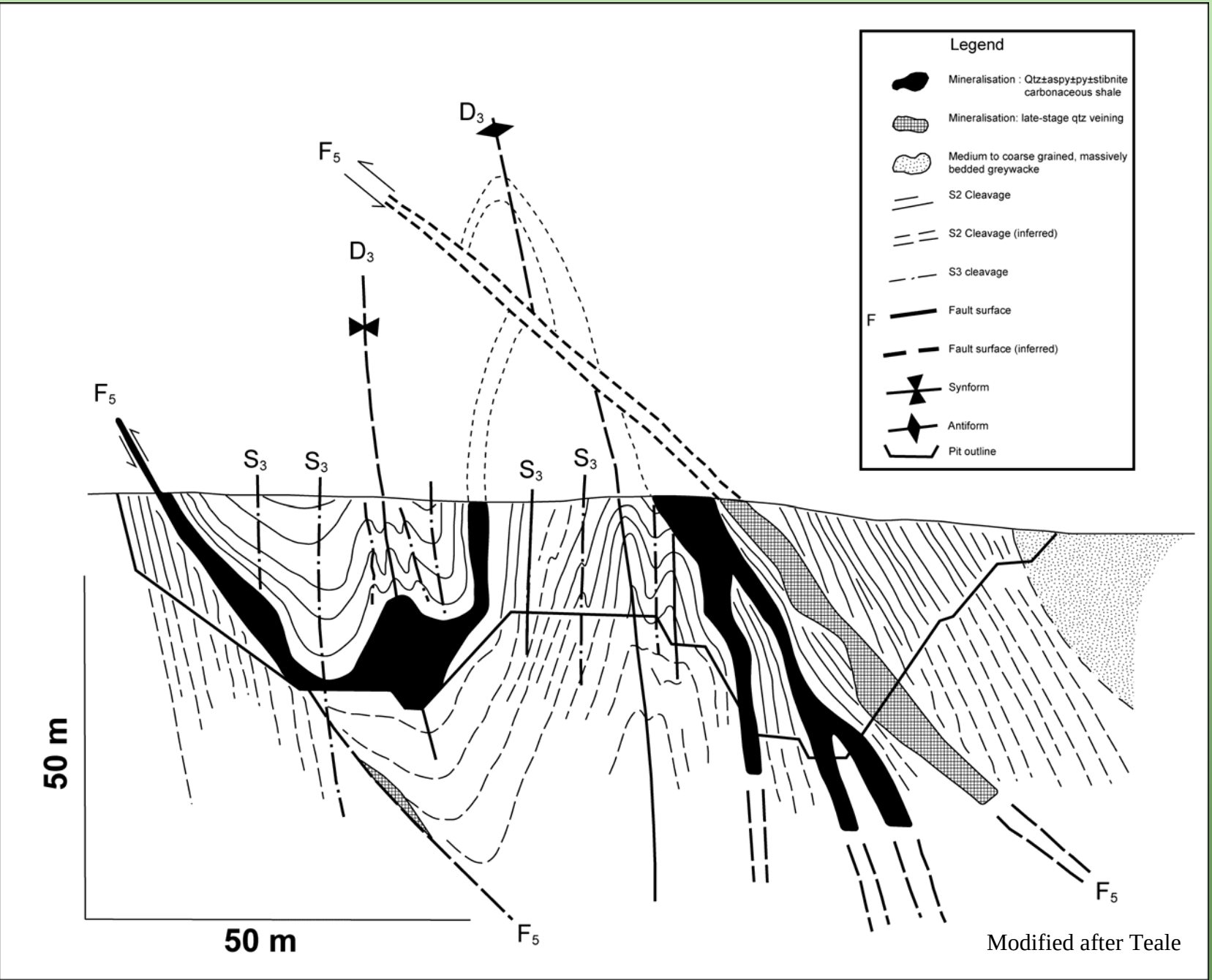

Modified after Teale

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Deformation history

Structural and temporal framework for deformation (GSQ):

D_1: NE-SW recumbent and isoclinal folding *(E. Dev)*

D_2: NE-SW upright isoclinal folding *(L.Dev-E. Carb)*

D_3: NW-SE striking thrust fault and open folding *(L. Carb)*

Our work:

Testing application of temporal framework to mineralisation (^{40}Ar-^{39}Ar)

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Deformation history and mineralising episodes

Syn-D1 mineralisation

- **Refolded NE-SW trending quartz-stibnite-gold lenses**
- **Confined within folded carbonaceous shale horizons**

D_1: NE-SW recumbent and isoclinal folding ***(E. Dev)***

D_2: NE-SW upright isoclinal folding ***(L.Dev-E. Carb)***

D_3: NW-SE striking thrust fault and open folding ***(L. Carb)***

Gold-bearing quartz-stibnite vein from the Camel Creek deposit

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Deformation history and mineralising episodes

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Syn-D2 mineralisation

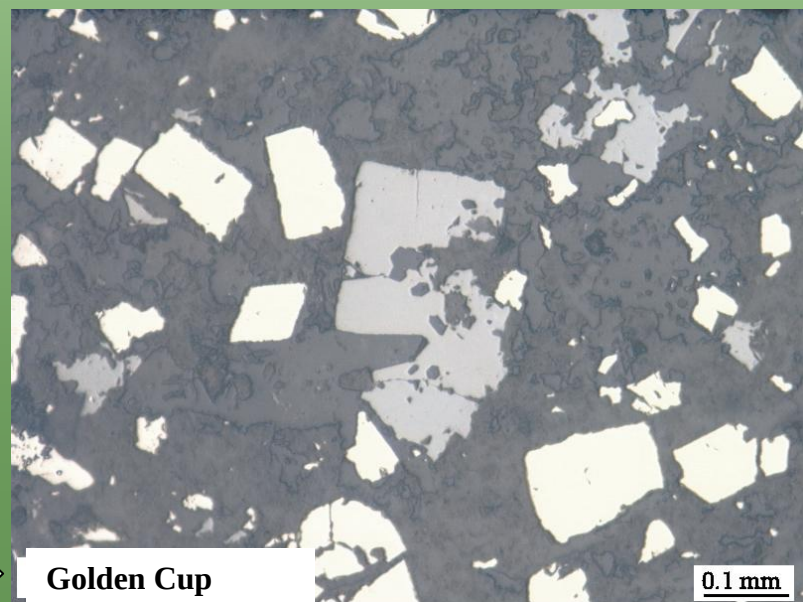
- **Boudinaged quartz veins / stockworks**
- **Confined within carbonaceous shales in NE-SW-striking shear zones // F2 axial plane**

D_1: NE-SW recumbent and isoclinal folding *(E. Dev)*

D_2: NE-SW upright isoclinal folding *(L.Dev-E. Carb)*

D_3: NW-SE striking thrust fault and open folding *(L. Carb)*

Gold-bearing arsenopyrite and pyrite at Golden Cup



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Deformation history and mineralising episodes

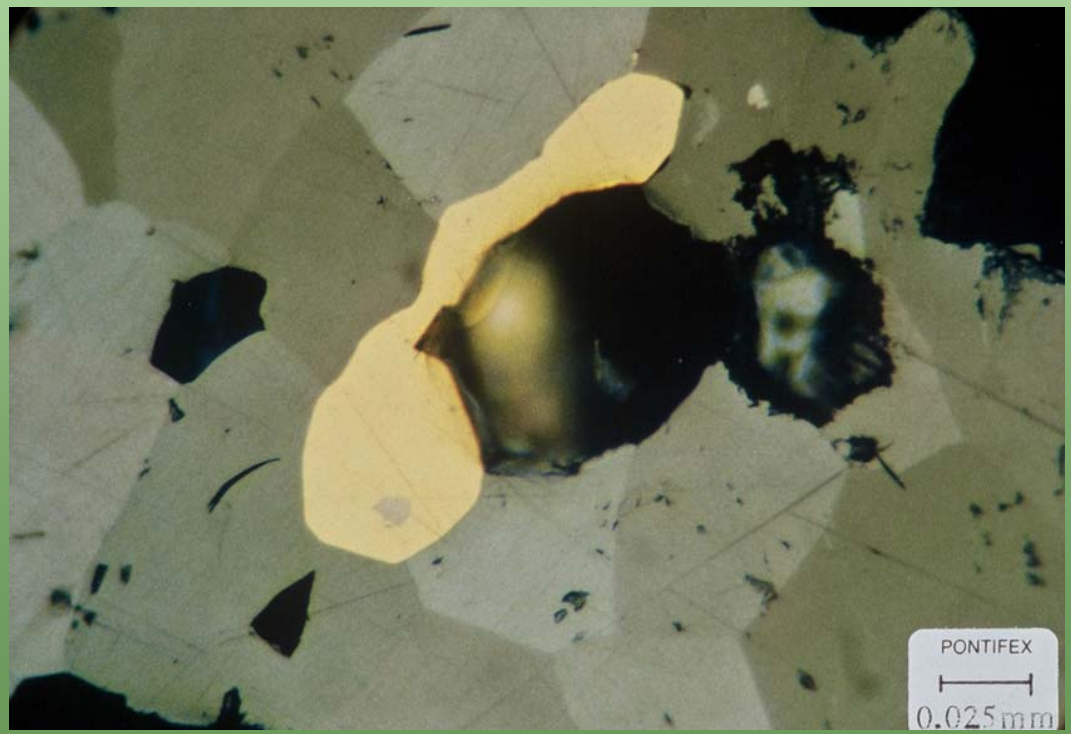
Post-D2/D3 mineralisation

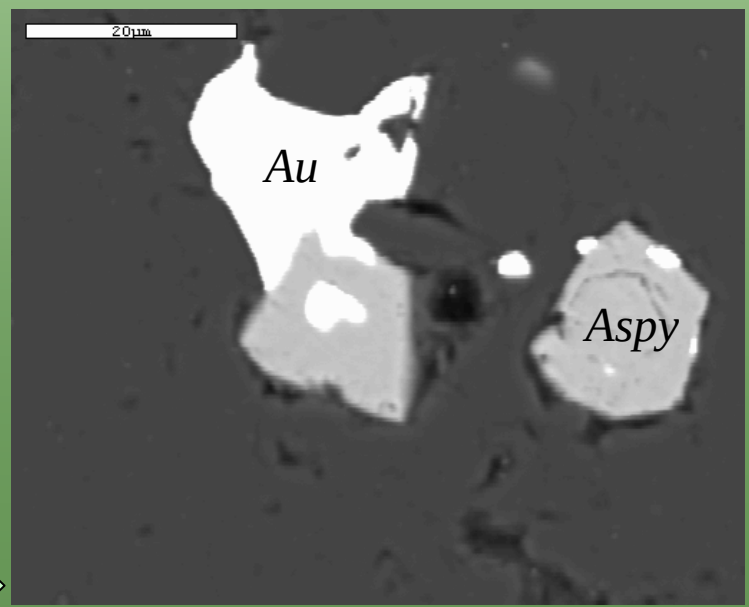
- **Gold-stibnite-aspy veins**
- **Confined within NW-SE trending extension fracture zones**

D_1: NE-SW recumbent and isoclinal folding *(E. Dev)*

D_2: NE-SW upright isoclinal folding *(L.Dev-E. Carb)*

D_3: NW-SE striking thrust fault and open folding *(L. Carb)*





Gold-Aspy association at Blue Gold (SEM image)

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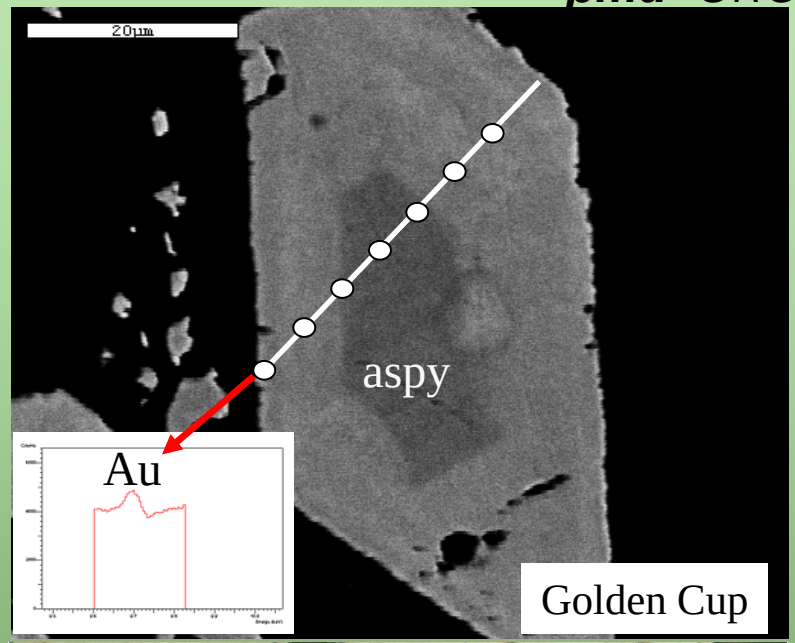
Sulphide paragenesis

		D_1	D_2	post-D_2/D_3
Airport Gold	Sphalerite Pyrite Arsenopyrite Gold			
Blue Gold	Arsenopyrite Rutile Galena Gold Pyrite Stibnite			
Camel Creek	Sphalerite Pyrite Arsenopyrite Stibnite Gold Aurostibite			
Golden Cup	Chalcopyrite Tetrahedrite Sphalerite Galena Pyrite Arsenopyrite Gold			
Red Gold	Chalcopyrite Tertrahedrite Pyrite Gold			



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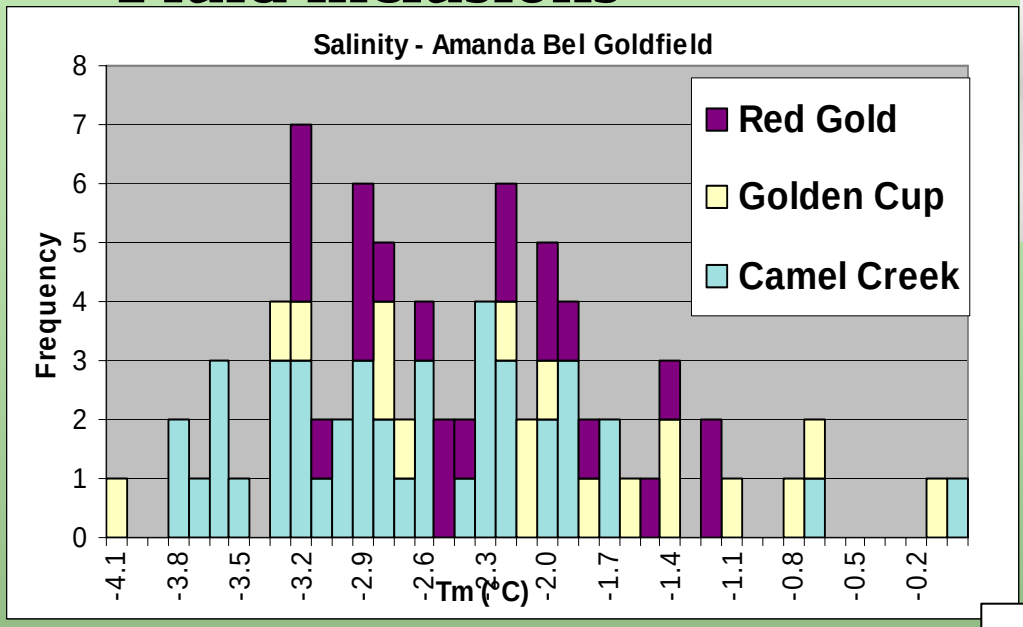
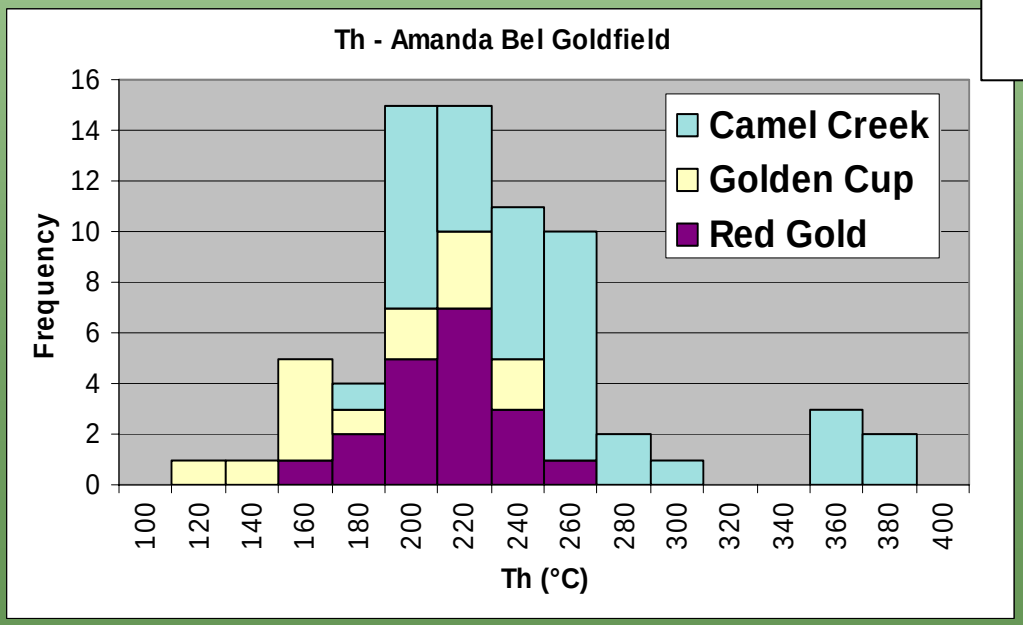
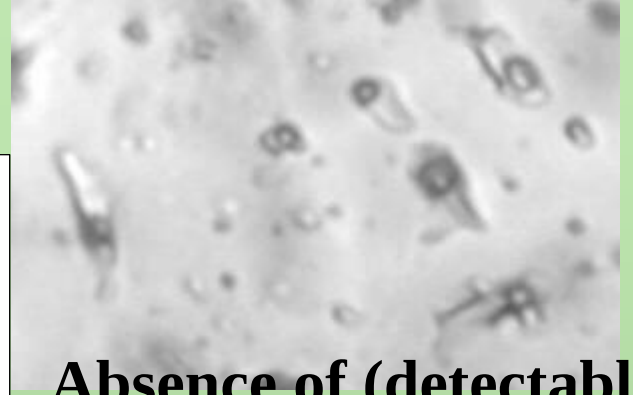
Fluid inclusions







Absence of (detectable) gas phases from Laser Raman

- **Fluid salinities between 2 and 5 wt% NaCl equiv.**
- **Th suggest minimal fluid trapping T between 160°C and 300°C**
- **D1 slightly higher salinities and Th then D2**

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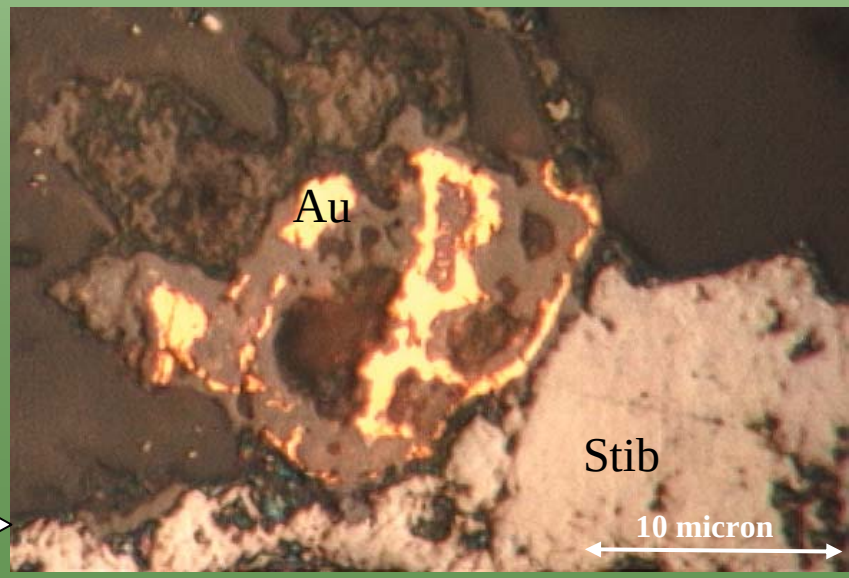
Implications and applications

Timing of gold mineralisation
(before major magmatic activity)

Nature of fluids
(metamorphic origin trapped at epizonal conditions)

Orogenic gold deposits

Close relationship with deformation
(in eastward younging fold-thrust belt)



Visible gold, aurostibite and stibnite from the Camel Creek deposit

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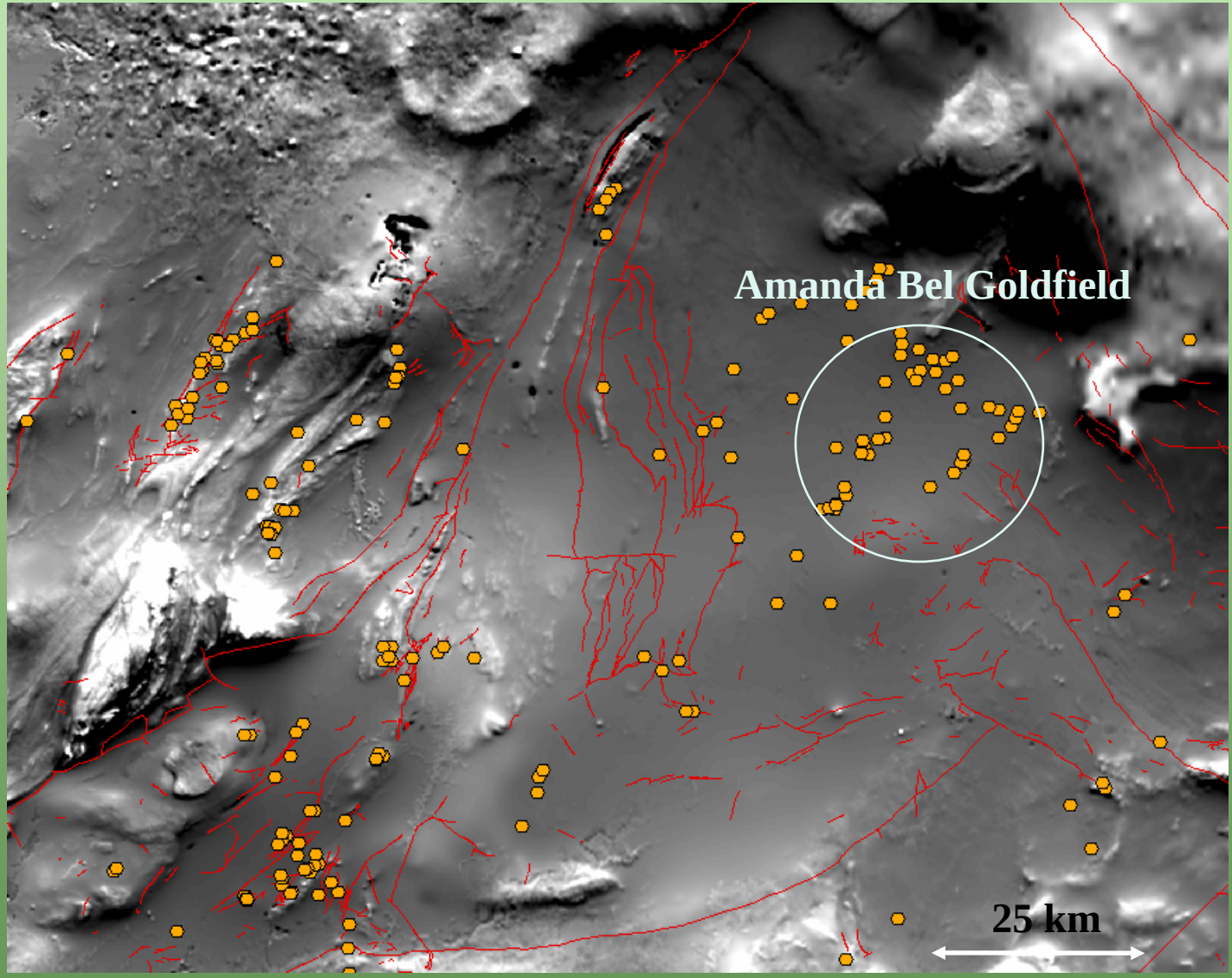
Implications and applications



Potential for gold mineralisation away from recognized fault structures

Challenge for future exploration

2. Palmerville Fault

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

Architecture and length
Association with (gold) deposits
Role in tectonic framework

→ Geophysics
Field studies

1st order

Palmerville Fault
Burdekin River Fault
Clarke River Fault

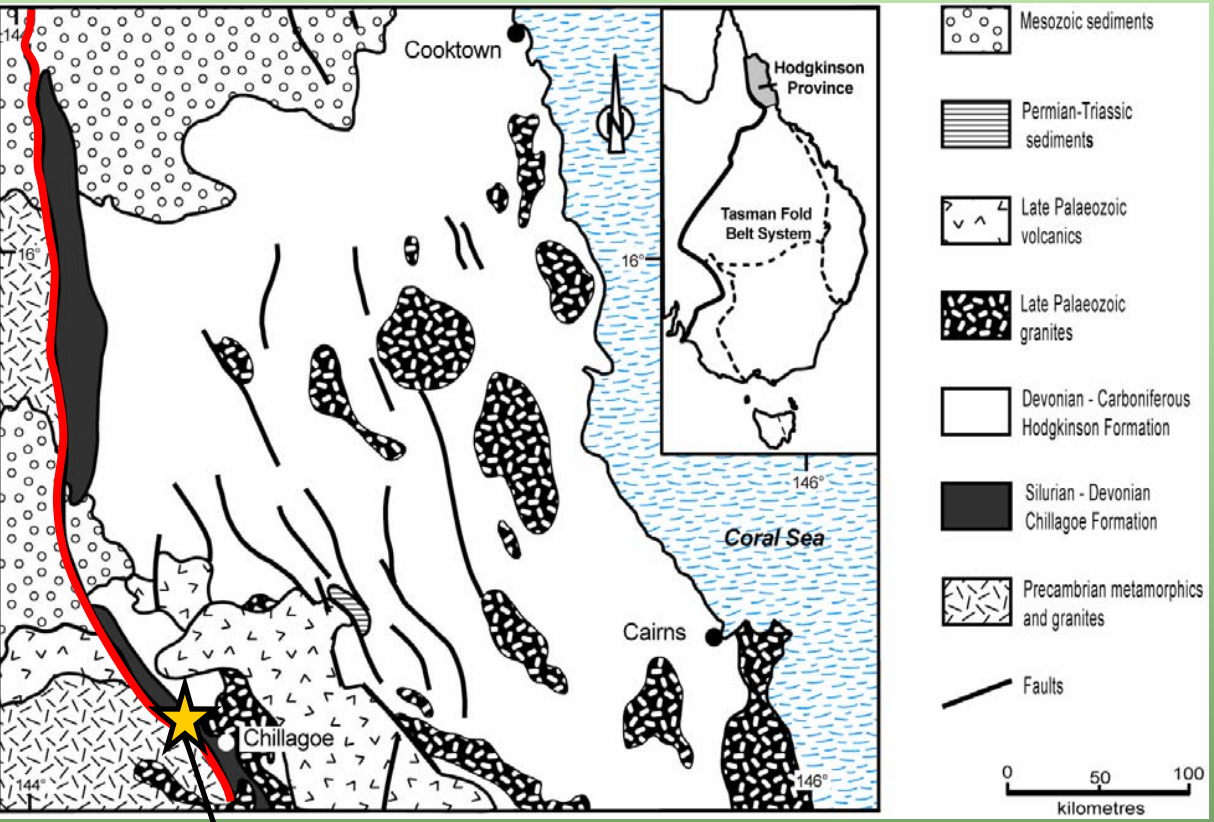
2nd order

Retina Fault
Kingsborough Fault
Amanda Bel Goldfield??

2. Palmerville Fault

Gold deposits are directly associated with the Retina Fault, a second-order structure to the Palmerville Fault in the Hodgkinson Province

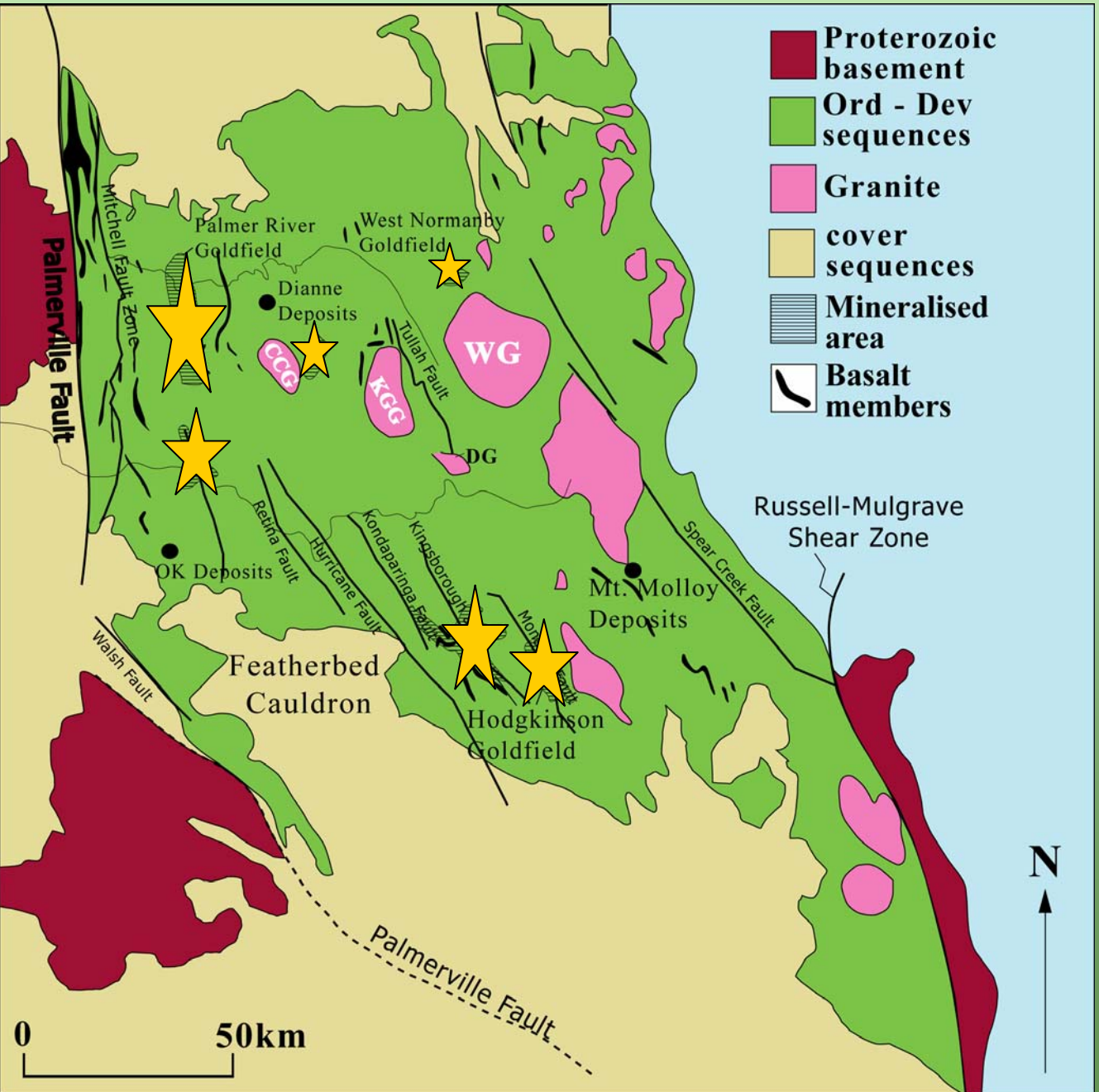
2. Palmerville Fault



Red Dome Au-Ag-Cu-Pb-Zn
12.8 Mt @ 2g/t Au and 0.5% Cu

- **Terrane boundary between Proterozoic and Palaeozoic sequences**
- **No direct association with mineralisation along NS section**
- **Pathway for Permo-Carboniferous granites associated with porphyry skarn deposits (e.g. Red Dome) along NW-SE section**
- **Enigmatic structure in terms of kinematics, tectonic evolution and its continuation southward**

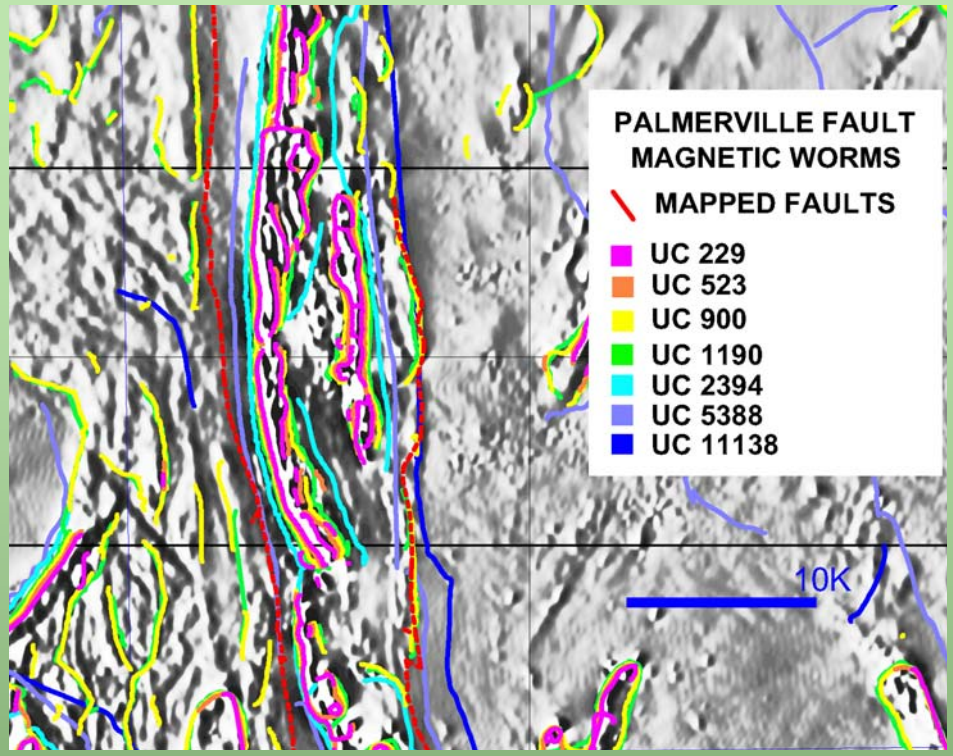
2. Palmerville Fault

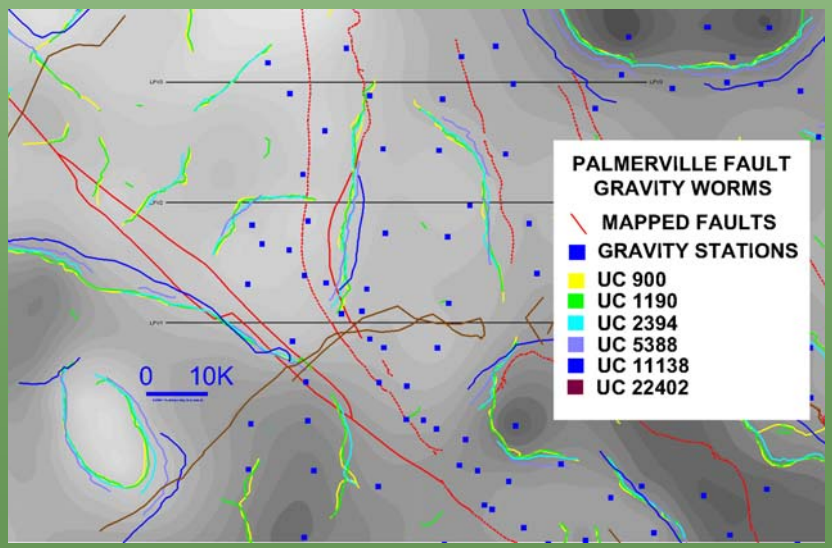


Hodgkinson Province

Significant mineralisation across a number of goldfields (>40t of Au, lode / alluvial)

2. Palmerville Fault





Geophysical modeling of PF

- **'Worming'**

  Test validity, significance and subsurface expression of PF

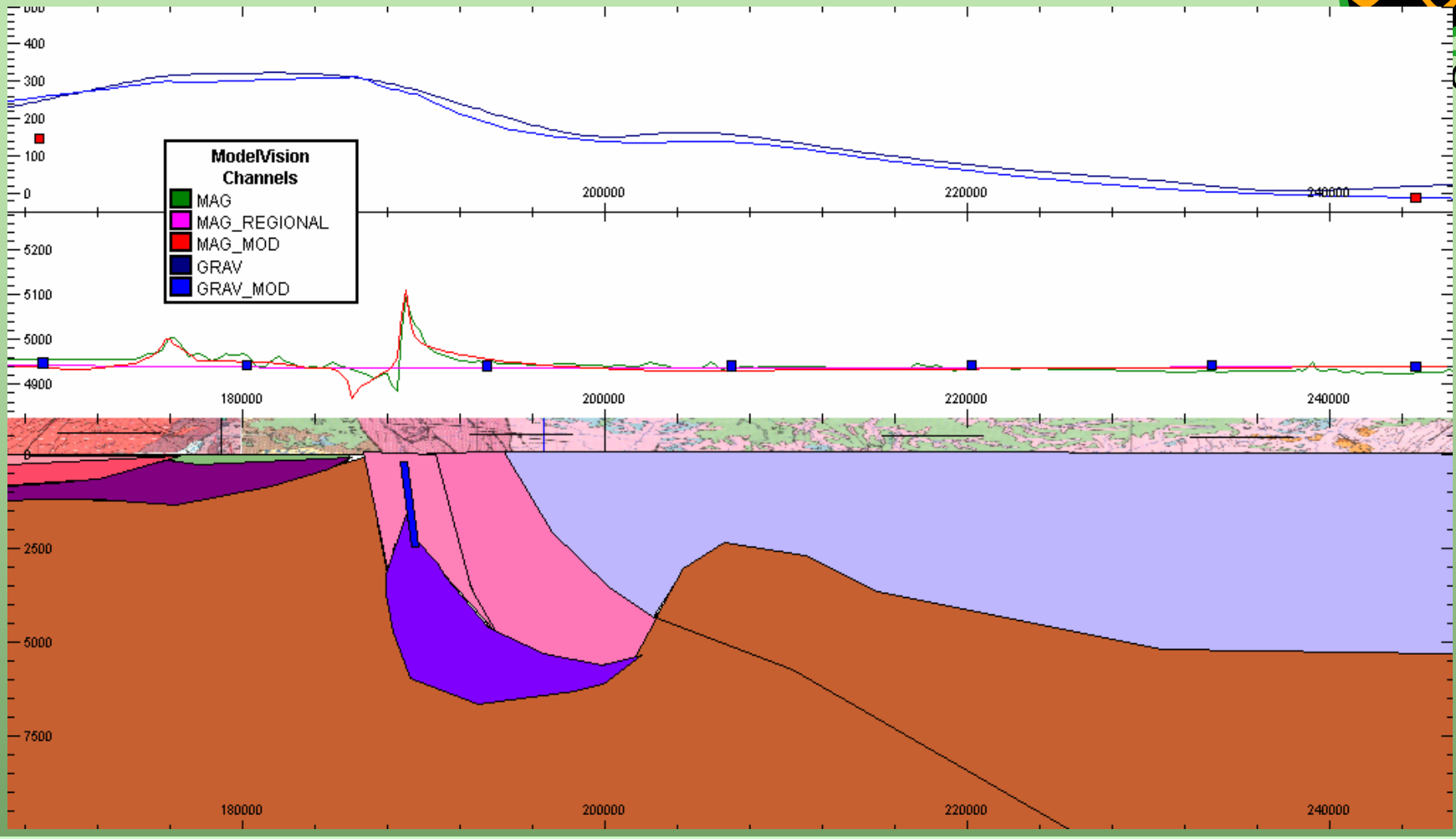
- **Forward modeling**

  Eastward-dipping model *supported by (limited) field observations*

- **Field observations**

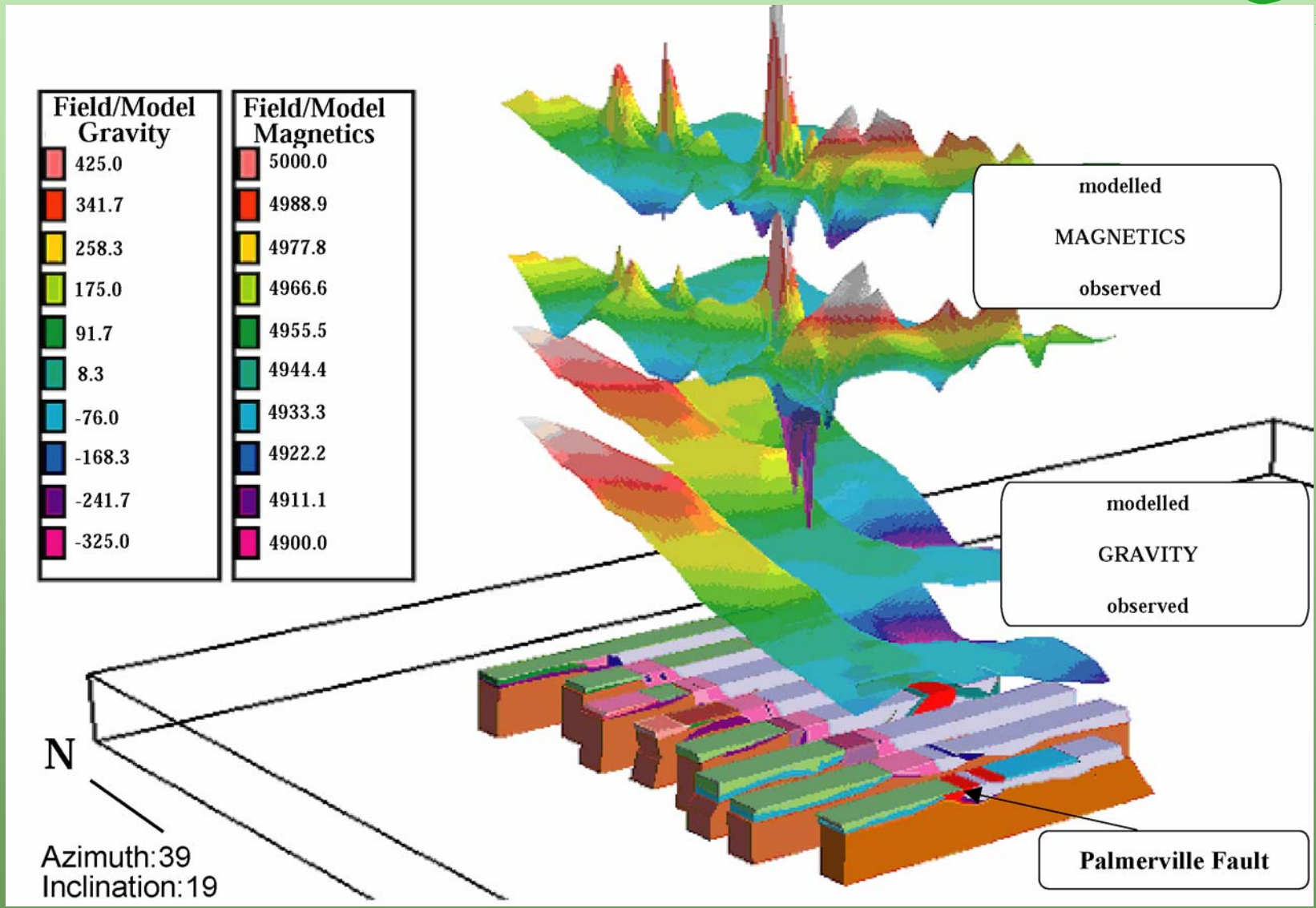
  Check results from geophysics

2. Palmerville Fault

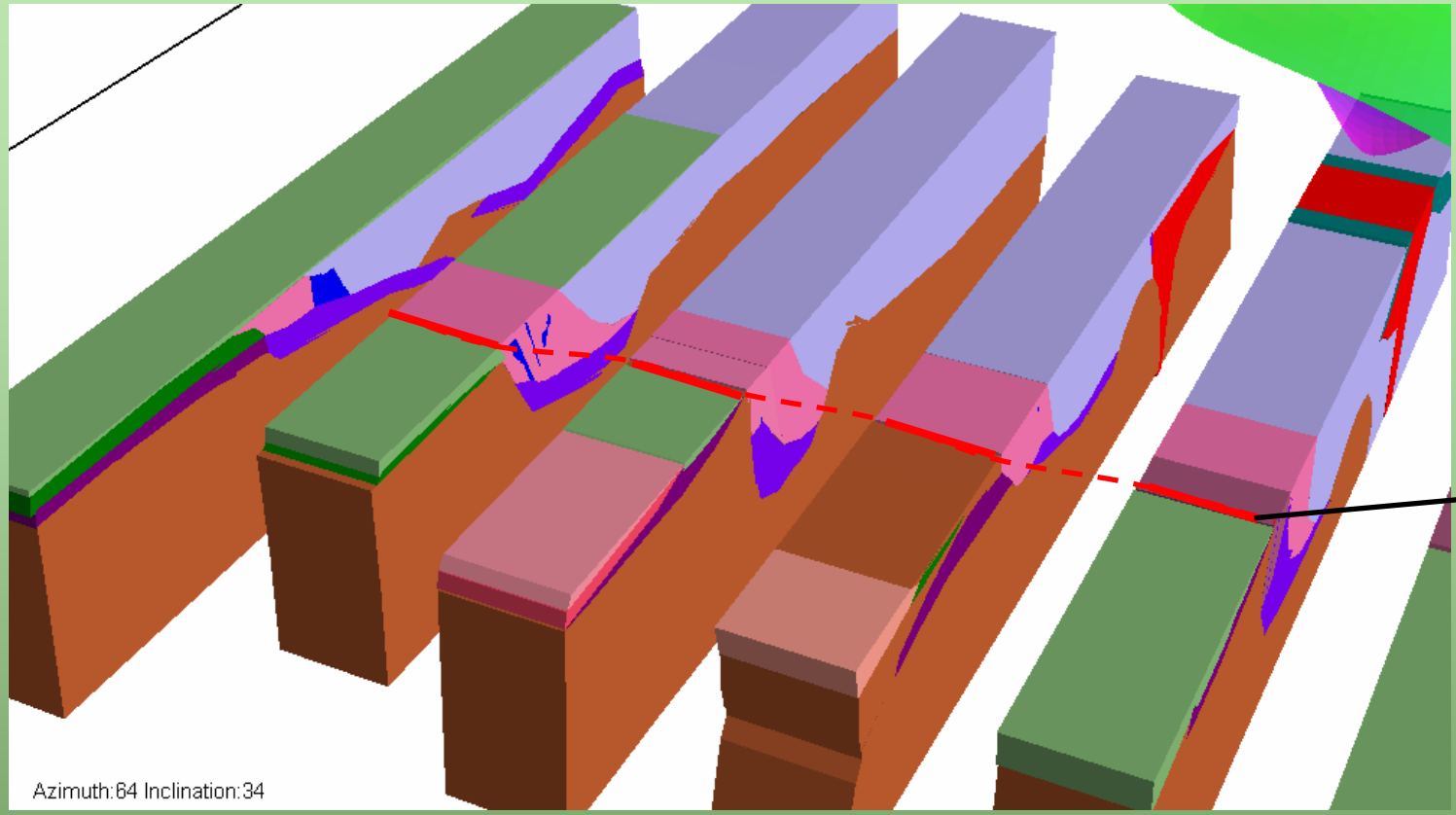


Subsurface structure of the Palmerville Fault and the Hodgkinson Province using ModelVision (forward modeling)

2. Palmerville Fault



2. Palmerville Fault



- **Worming indicates presence of near-vertical structure at the surface, becoming listric at deeper levels.**
- **Gravity / magnetics expressions suggest presence of continental basement underneath the HP confirming previous studies on granite geochemistry**

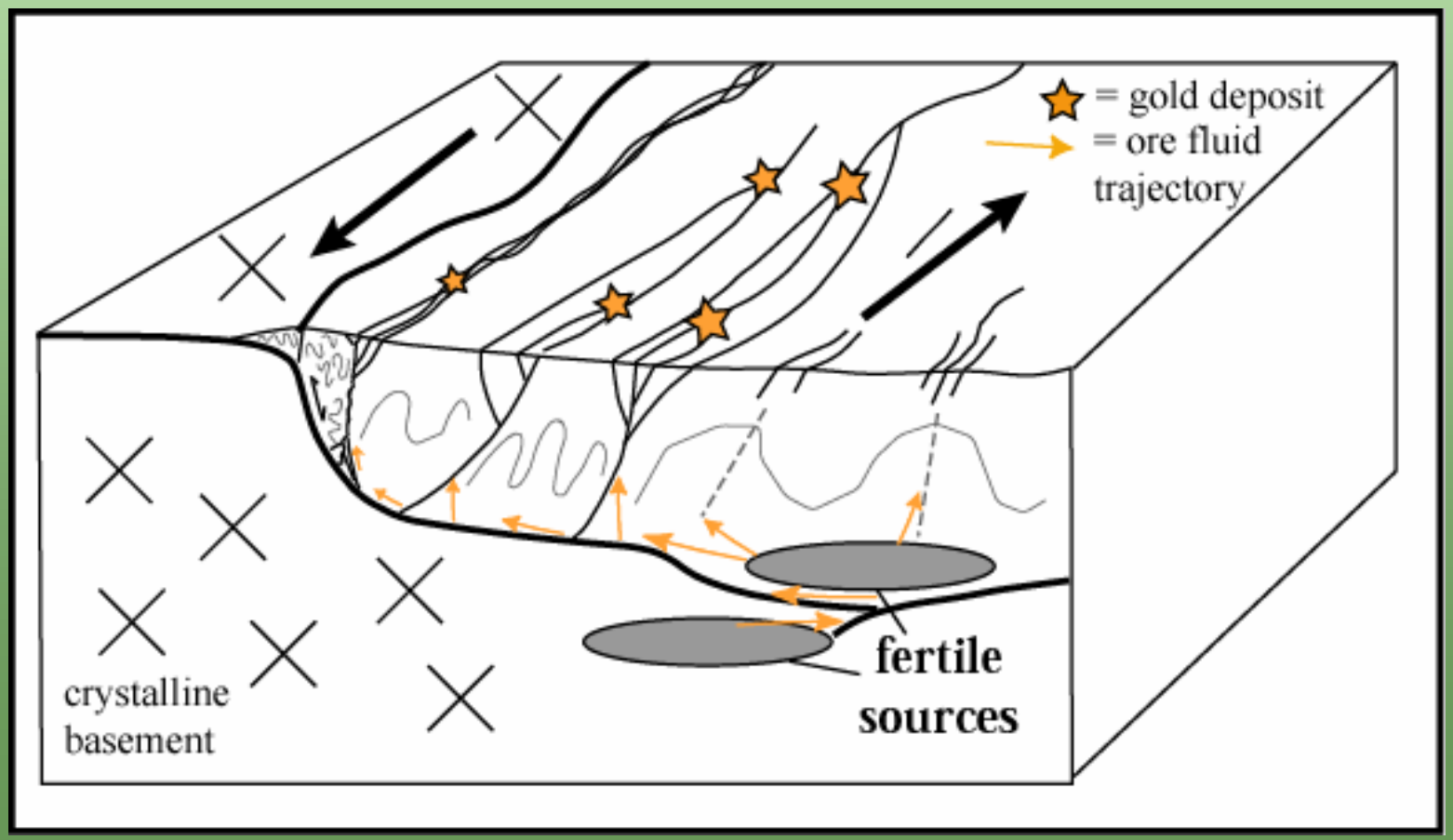
symmetric lithospheric extension with acceleration from early Devonian

2. Palmerville Fault

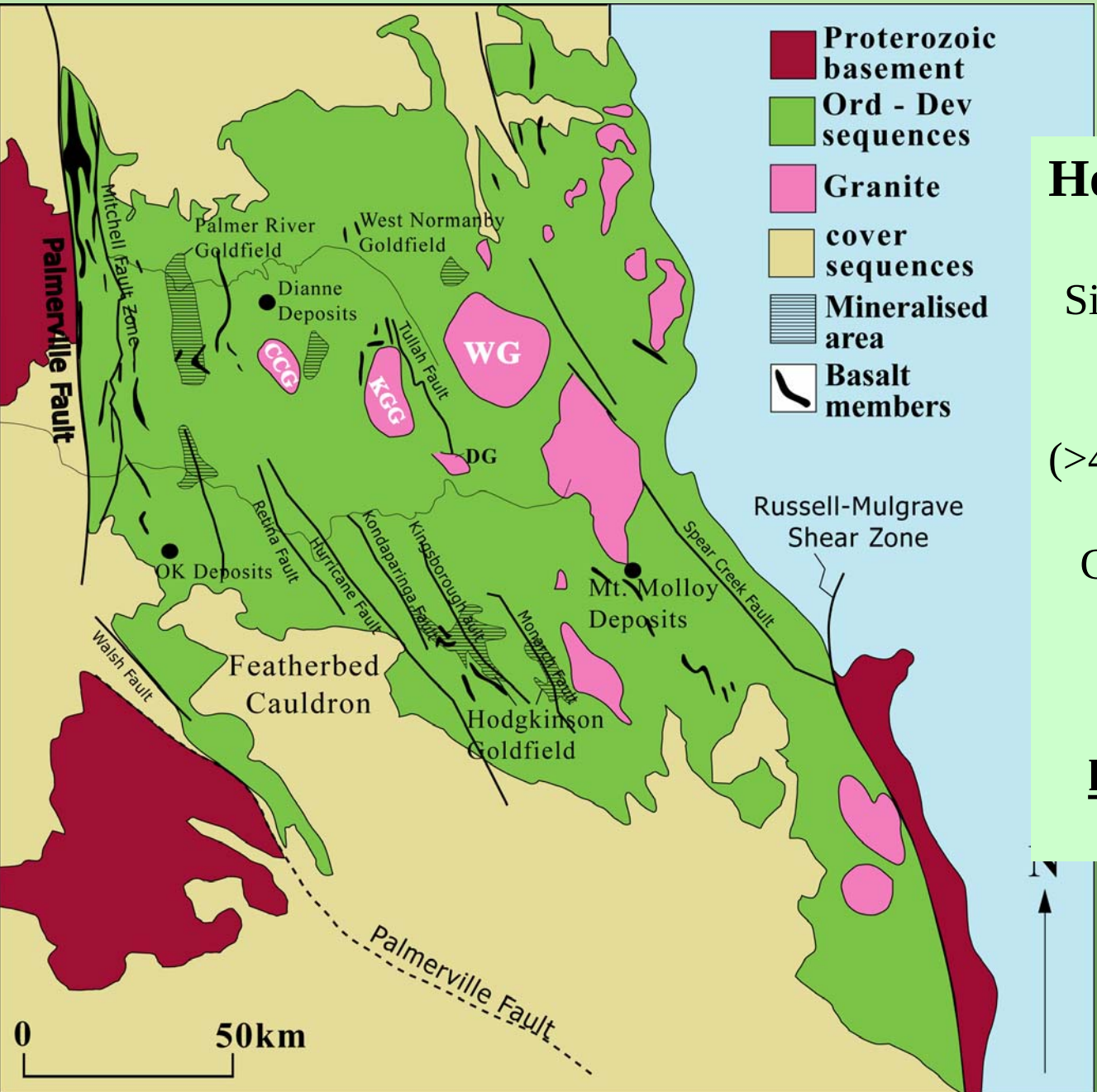
Why is the Palmerville Fault poorly endowed???

- PF functioned as backbone structure from which fluids were drained by subsidiary structures

- Absence of structural complexity



3. Basalt geochemistry



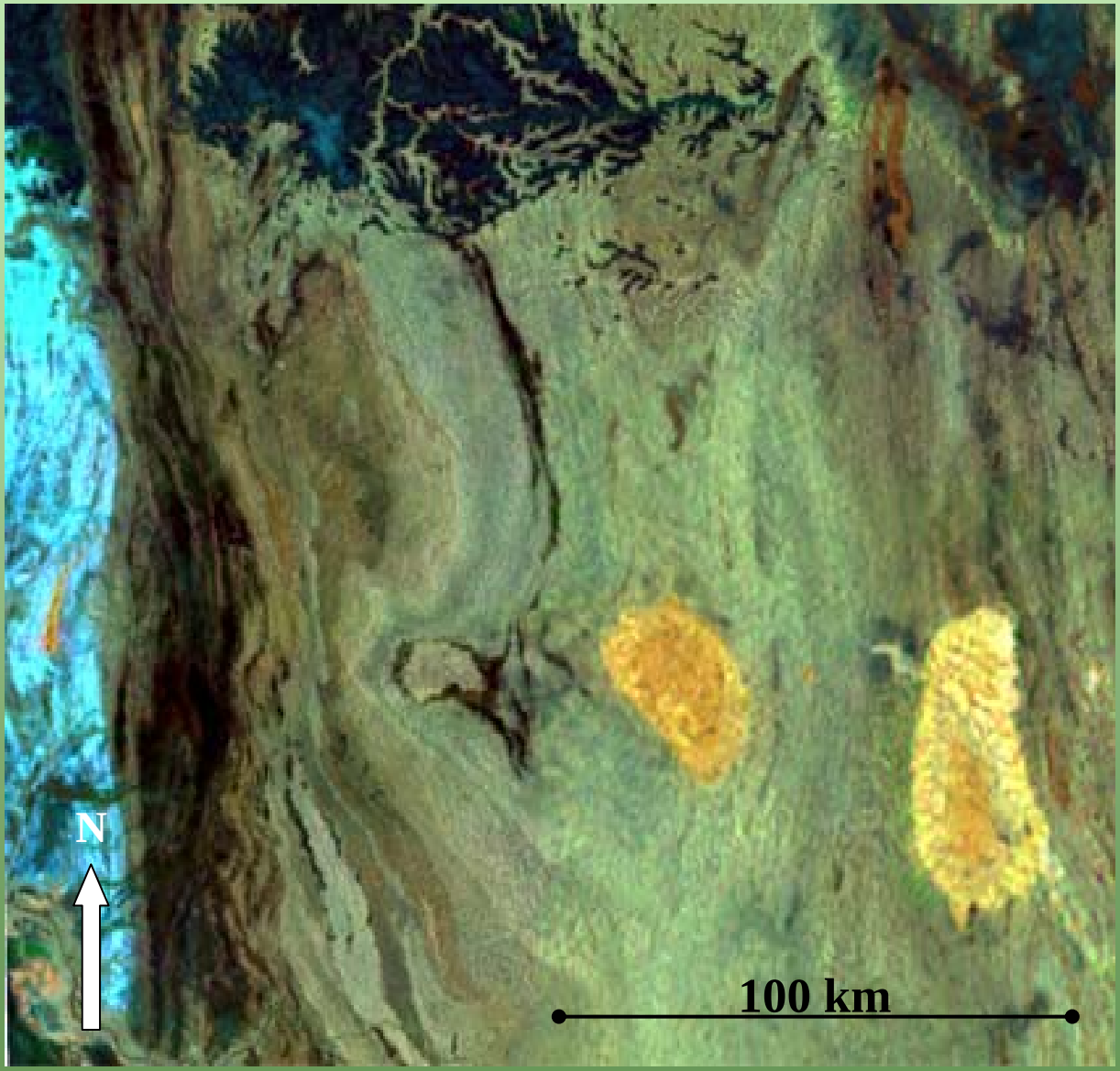
Hodgkinson Province

Significant mineralisation across a number of goldfields (>40t of Au, lode / alluvial)

Controversy on tectonic evolution

Basalt units…
<u>key to tectonic setting</u>

3. Basalt geochemistry



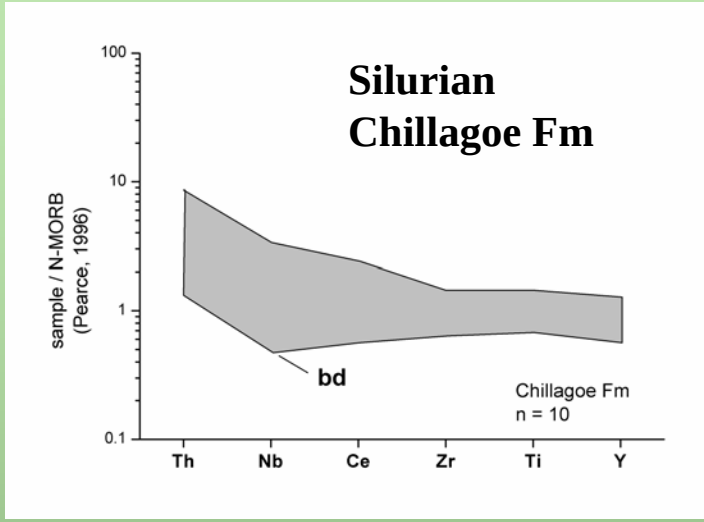
Basalt units in eastward younging stratigraphic sequence:

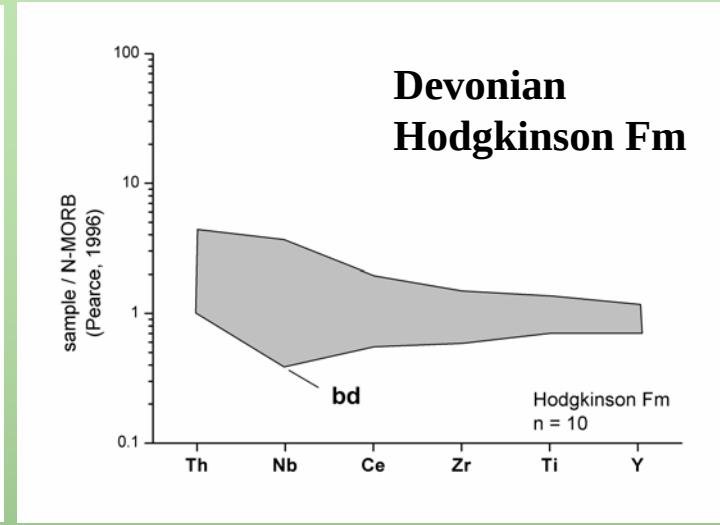
1. **Ordovician Mulgrave Fm**
2. **Silurian Chillagoe Fm**
3. **Devonian Hodgkinson Fm**
4. **Dev/Carb dolerite and granite intrusions**

sampled and analysed for major, trace and rare earth elements

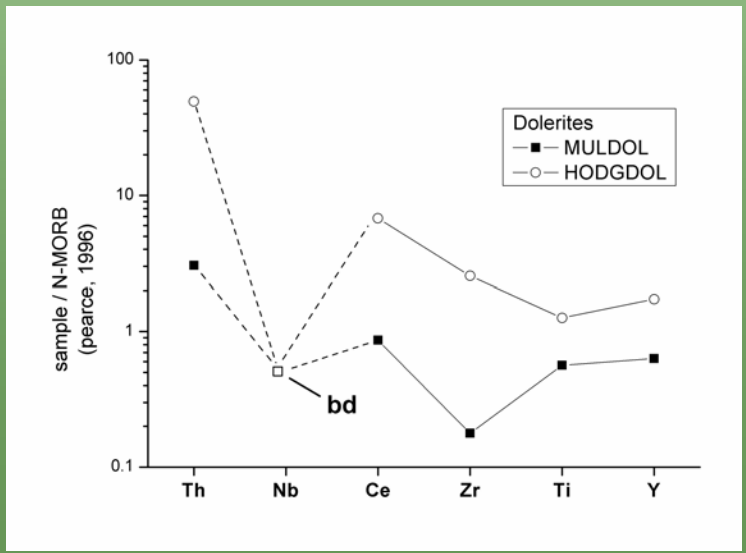
Radiometric image of the northern section of the Hodgkinson Province

3. Basalt geochemistry



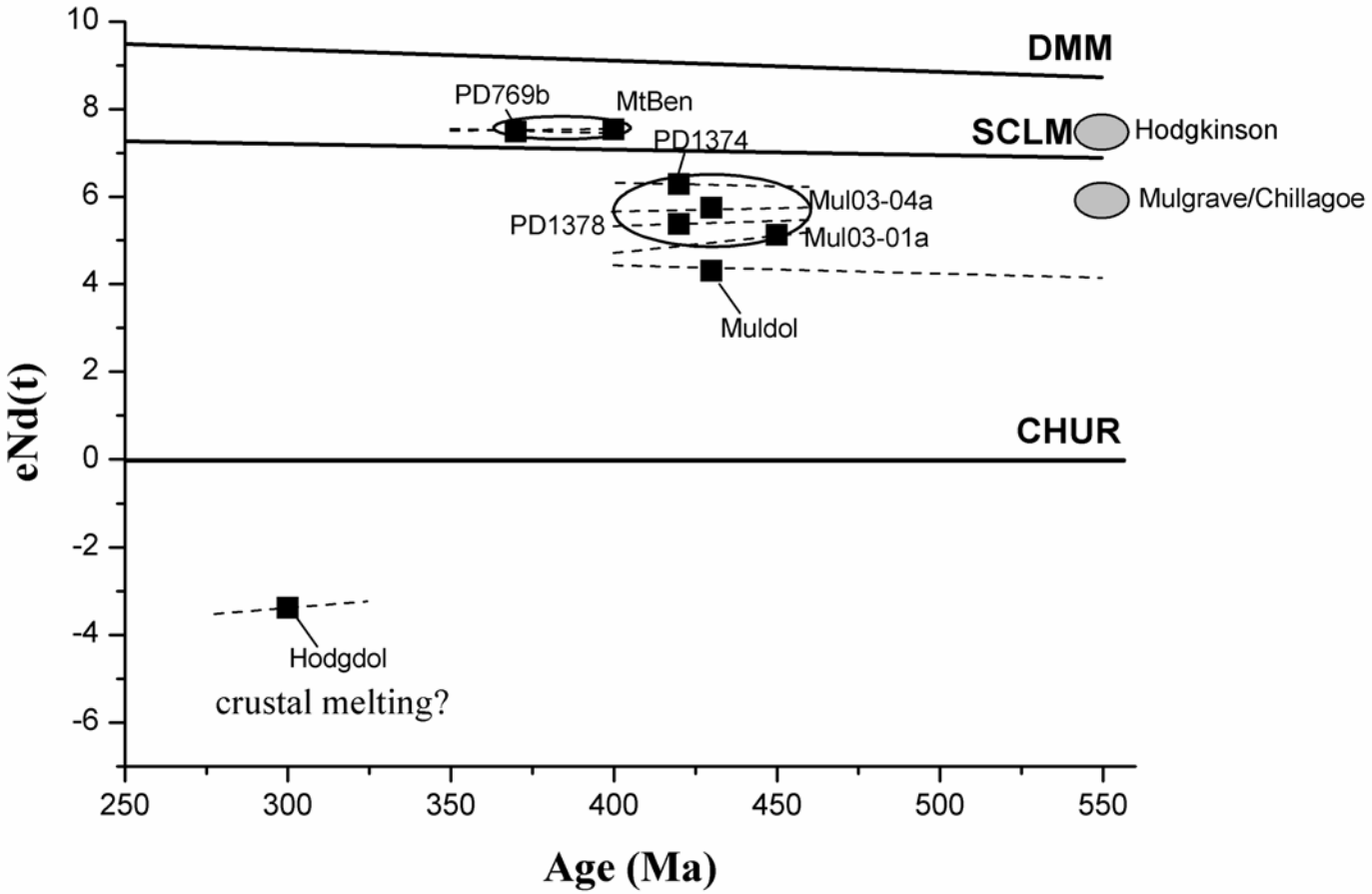


MORB related volcanics formed in extensional setting (back-arc)



HodgDol – dolerite intrusion sourced from continental crust in compressional setting

3. Basalt geochemistry

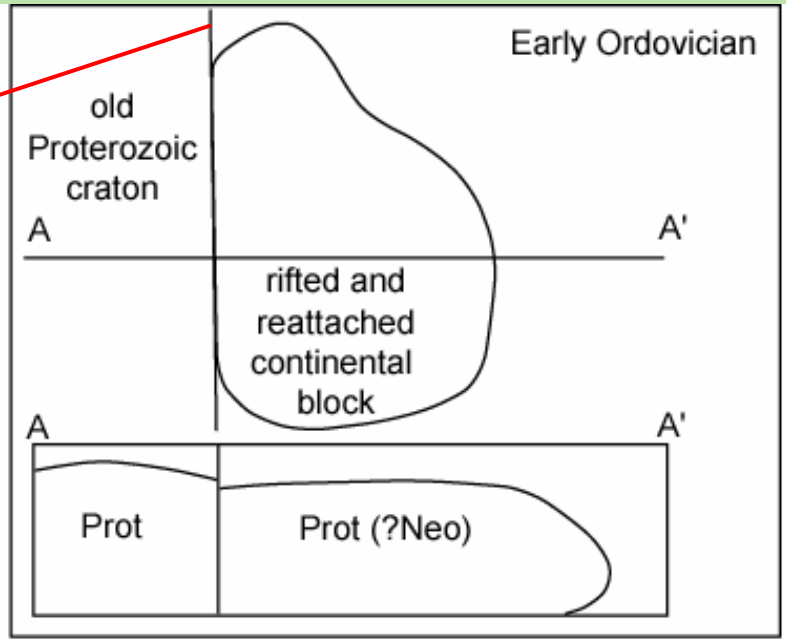


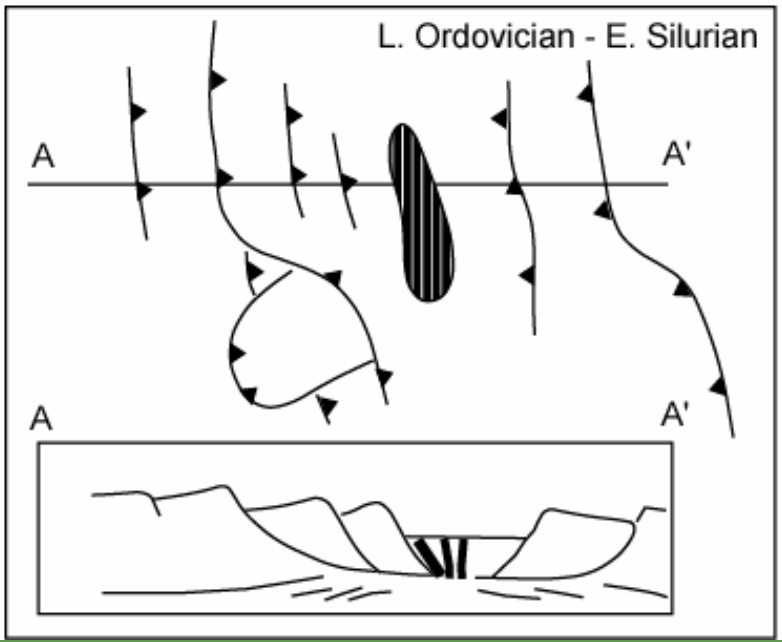
Sm-Nd data showing two distinct groupings both contaminated by continental crust:

1. **Ordovician – Silurian basalts derived from SCLM**
2. **Devonian basalts derived from asthenosphere**

3. Basalt Geochemistry

PF

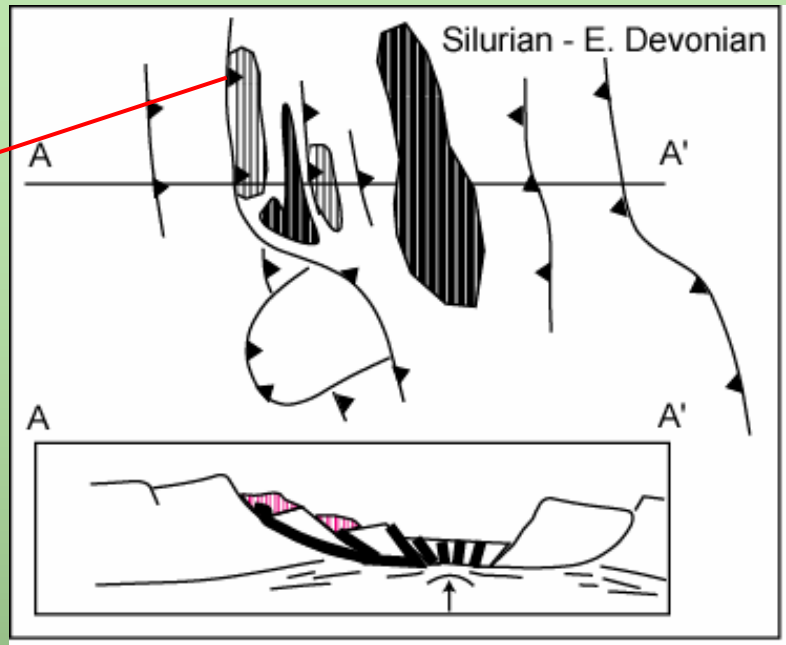




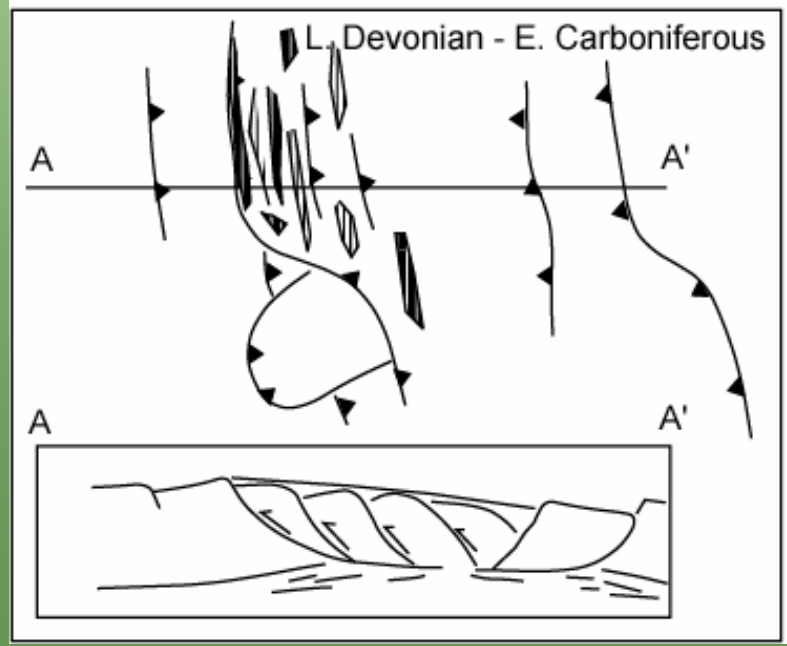
continental crustal extension
some minor basalt outpourings

3. Basalt Geochemistry

PF

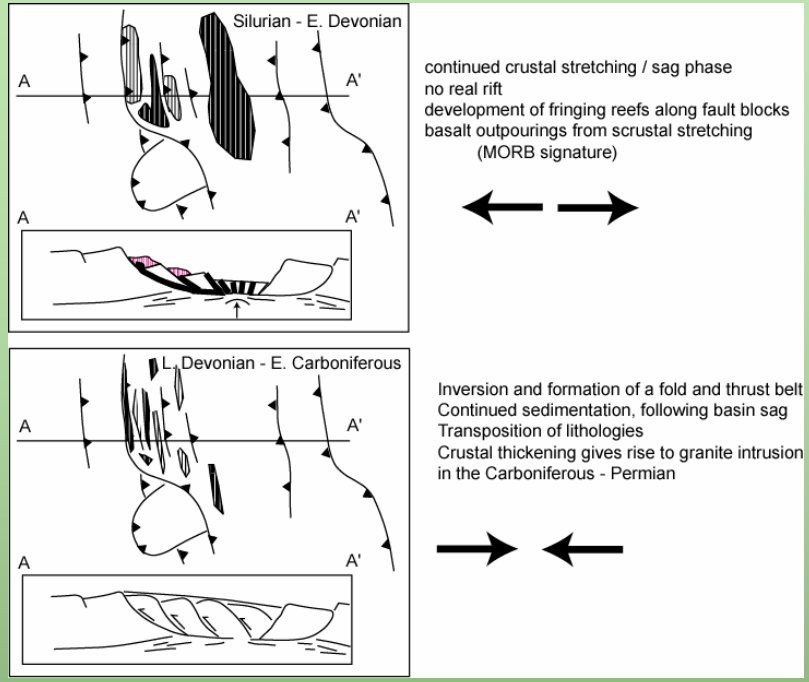


continued crustal stretching / sag phase
no real rift
development of fringing reefs along fault blocks
basalt outpourings from scrustal stretching
(MORB signature)



Inversion and formation of a fold and thrust belt
Continued sedimentation, following basin sag
Transposition of lithologies

3. Basalt Geochemistry



Tectonic model in agreement with observations from geophysical modeling of Palmerville Fault

But…..
What controls the tectonic evolution
subduction rollback?

Where is the arc??

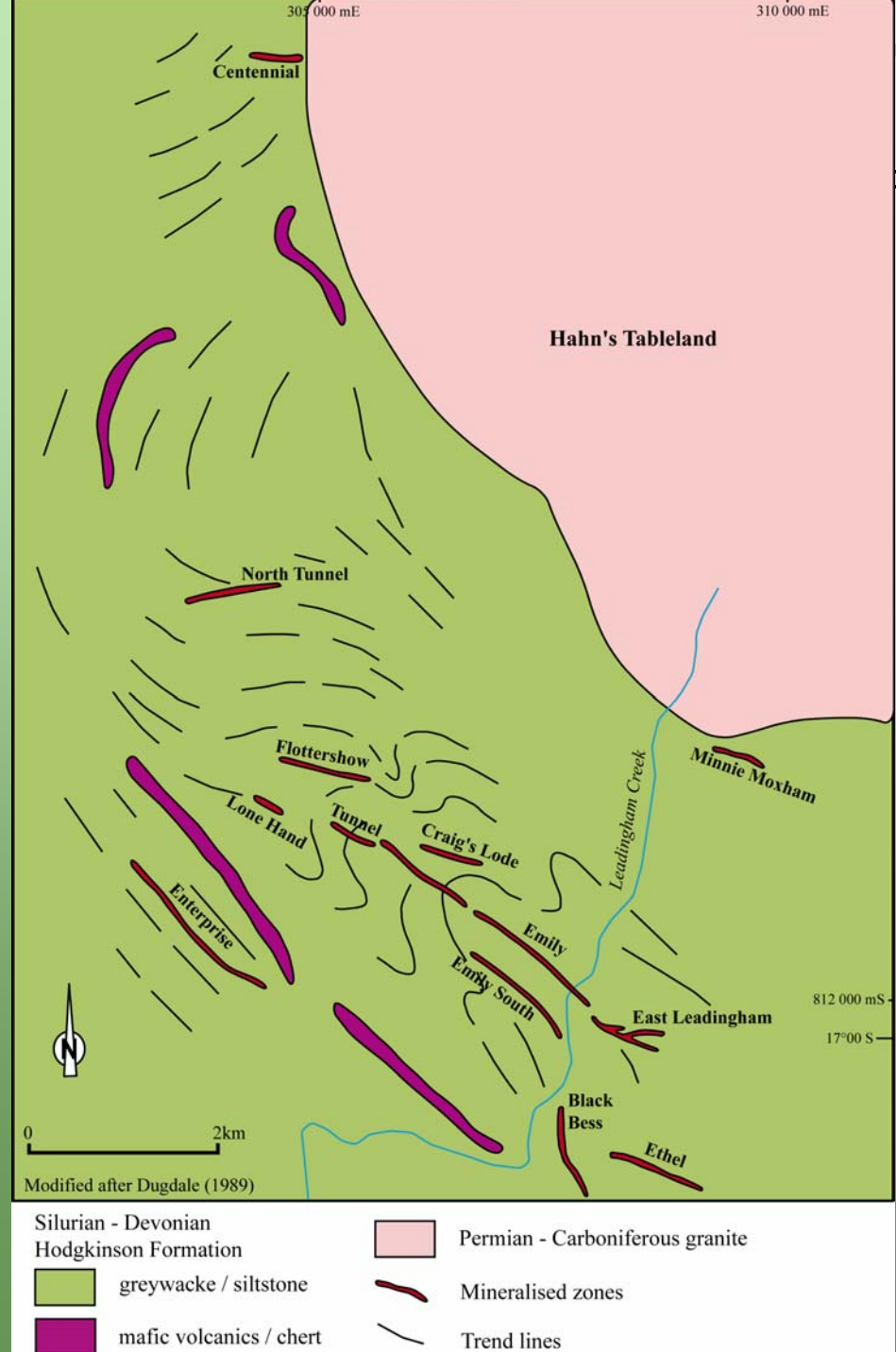
4. Northcote District

Northcote district
Hodgkinson Goldfield
(Bulls Pinnacle area)

- Overall NW-trend in gold deposits

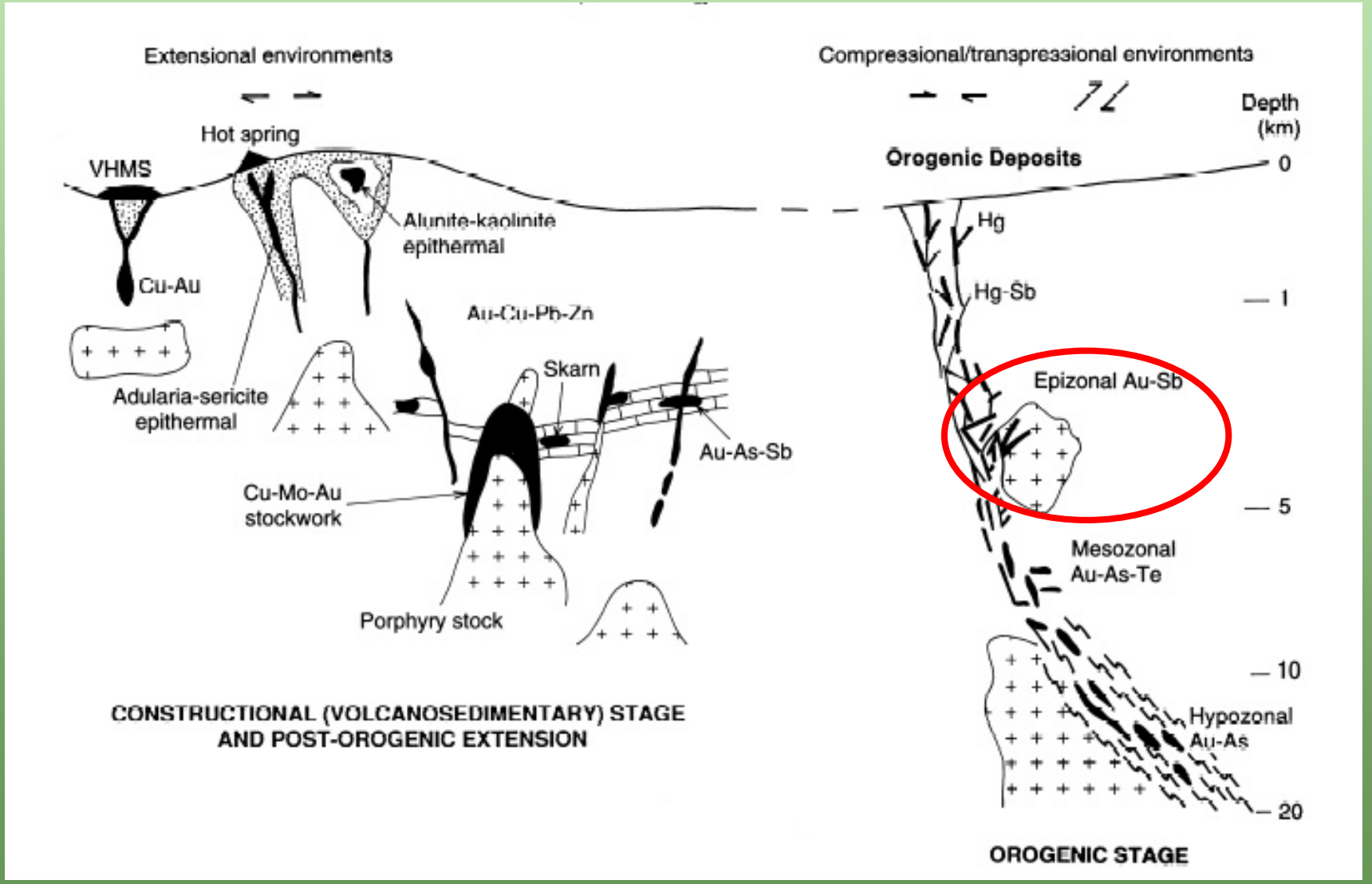
- Mineralisation is hosted along steeply-dipping reverse faults

- Orogenic gold mineralisation i.e. gold deposited during accretionary episodes



4. Northcote Disctrict

Orogenic epizonal Au-Sb deposits



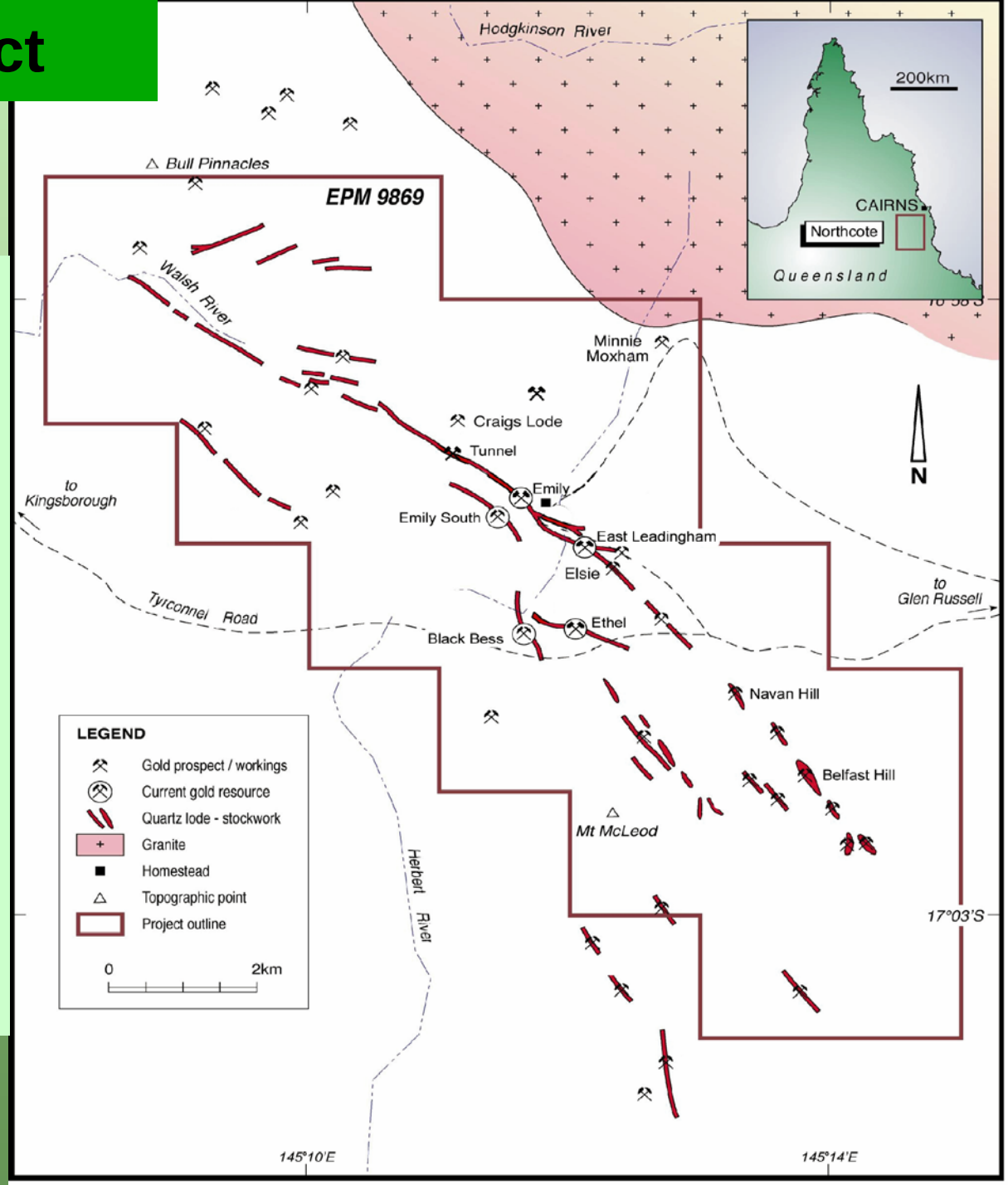
4. Northcote District

Mineralisation style

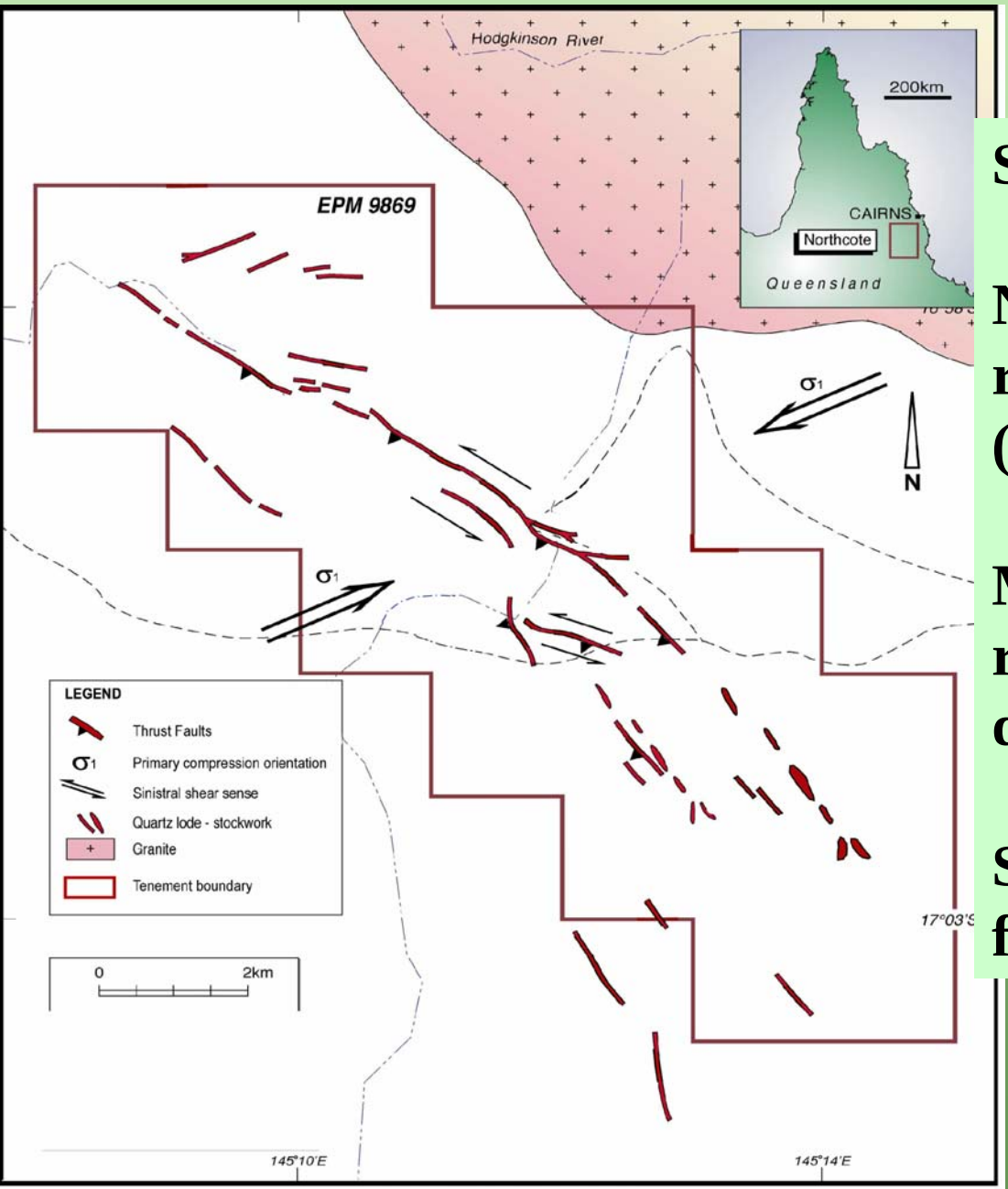
Refractory gold mineralisation (Au in py / asp)

Gold associated with asp, py, po, cpy and gl and late-stage stibnite

Ser, asp and py alteration of host rocks



4. Northcote District



Structure:

NW striking, steeply dipping reverse faults and shear zones (and associated splays)

Mineralisation controlled by rheological contrasts along dilatancy zones (jogs)

Sinistral wrenching resulting from east-west compression

4. Northcote District

Structural work from Hodgkinson Goldfield

Stibnite-bearing quartz vein with cross-cutting late-stage barren quartz veins from the Emily deposit

Pre-mineralisation D_2-fold structures from the Emily South deposit

4. Northcote District

Inferred structural history

D1 (Early Devonian)

Isoclinal folding with shallowly plunging,

steeply dipping NW-trending axes associated with well-defined cleavage sub-parallel to S_0

D2 (Late Devonian-Early Carboniferous)

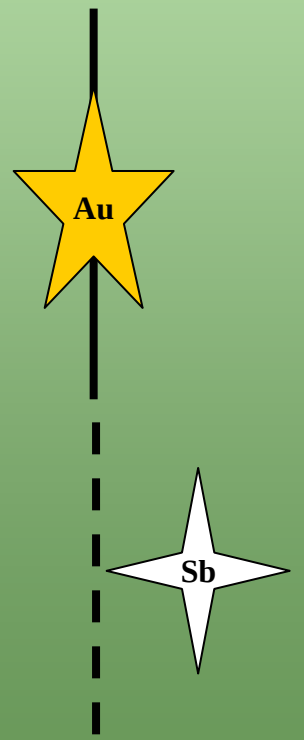
NW-SE trending, upright (moderately tight) folding

D3 (Late Carboniferous)

NW-trending thrust faulting // F_2 axial planes

D4 (Early Permian) – Minnie Moxham

N to NE trending kink folds and E-W trending tensional fractures



4. Northcote District

Ongoing work:

- Fluid inclusion microthermometry (ore fluid characteristics)
expected: metamorphic fluids, with minor magmatic input
i.e. Minnie Moxham

- Sulphide paragenesis (and association with structural history)

- Local oreshoot alteration profile

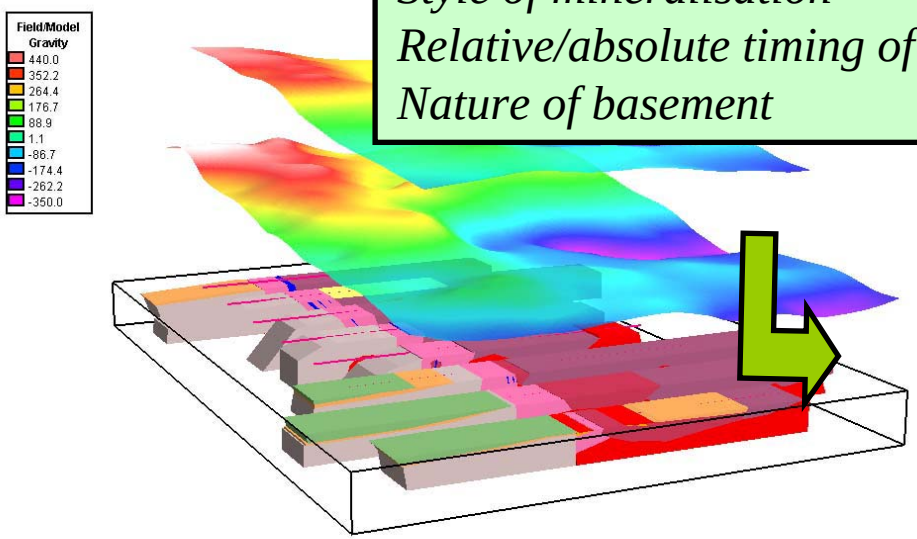
Predictive Mineral Discovery

Multi-disciplinary research…..

Geology / Geochronology
Geophysical targeting tools/modeling
Geochemistry

towards…..

Mapping out deformation episodes
Kinematics and nature of faults
Style of mineralisation
Relative/absolute timing of mineralisation
Nature of basement



predictive mineral discovery

(Fault) control on mineralisation
Endowment (quantity)
Tectonic evolution

pmd*CRC

Preliminary results:

- **Regional correlation between deformation and gold mineralisation**
- **Regional genesis of orogenic gold deposits associated with low CO_2-bearing metamorphic fluids**
- **Spatial relationship of gold mineralisation with 2nd-order faults**
- **Presence of continental basement underneath HBRP**
- **Gold genesis in back-arc basin setting**
- **Palmerville Fault indirect control on mineralisation**

Hallmarks of another Fosterville, Muruntau, Sukhoi Log ???

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PhD thesis

Expected date of submission: August 2005

Thesis outline:

* Introduction
* **Characterisation of gold genesis in ABG and HG** (incl. absolute age dating of gold deposits / deformation events)
* **Geochemistry as a key to tectonic setting**
* **Geophysical investigations and modelling** in the Hodgkinson Province / Broken River Province
* **Tectono-metallogenic evolution of the northern TFBS**
* **440 Ma gold mineralisation** in SE Australia: significance of tectonic mode switching and mega-subduction zones
* Conclusions