

Y3/M358 – Hydrothermal Alteration Footprints

Steffen Hagemann, Peter Neumayr, John Walshe, Kaus Petersen, Susan Driberg, (Glen Masterman), (Leo Horn), Louis Gauthier, Mherdad Heydari, Joanna Hodge, Daniel Howe, Kate Moran, Sian Nichols

Y3 – Hydrothermal Alteration

Work group

Aims/Philosophy

**Camp- to Deposit-scale Multiple
Alteration and Ore Footprint.....**

Scale and method integration....

**Kalgoorlie-Kambalda
corridor.....**

Present/Future Results

Present Results:

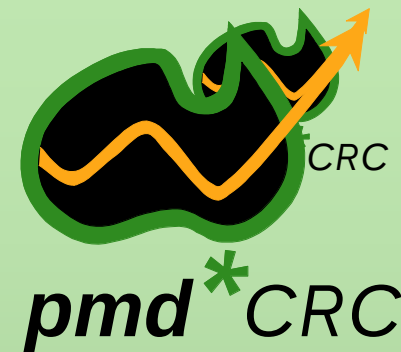
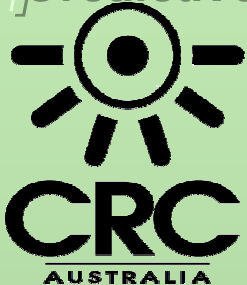
- Mine-camp-regional studies
- Integration and interpretation of data from different scales
- Exploration criteria: ore-shoot to camp to district.....

Future:

- Export results (pattern) and outstanding problems to other gold camps in the Yilgarn and/or other Archean cratons worldwide
- Poster John Walshe..... synthesis by Peter Neumayr later in the talk.....

Outline

- **Intro: where..... who.....when....**
- **Peter Neumayr:Alteration Kambalda**
- **Klaus Petersen:Fluids Kambalda**
- **Joanna Hodge:Structural and Fluid
Evolution at New Celebration**
- **Susan Driberg:Perspective
Wallaby**
- **Peter Neumayr:The Future**



Camp- to thin section-scale spatial zonation and temporal evolution of hydrothermal alteration assemblages at the St. Ives gold camp, Western Australia

Peter Neumayr¹, John Walshe², Klaus Petersen¹,
Steffen G. Hagemann¹, Leo Horn², Robert Morrison³

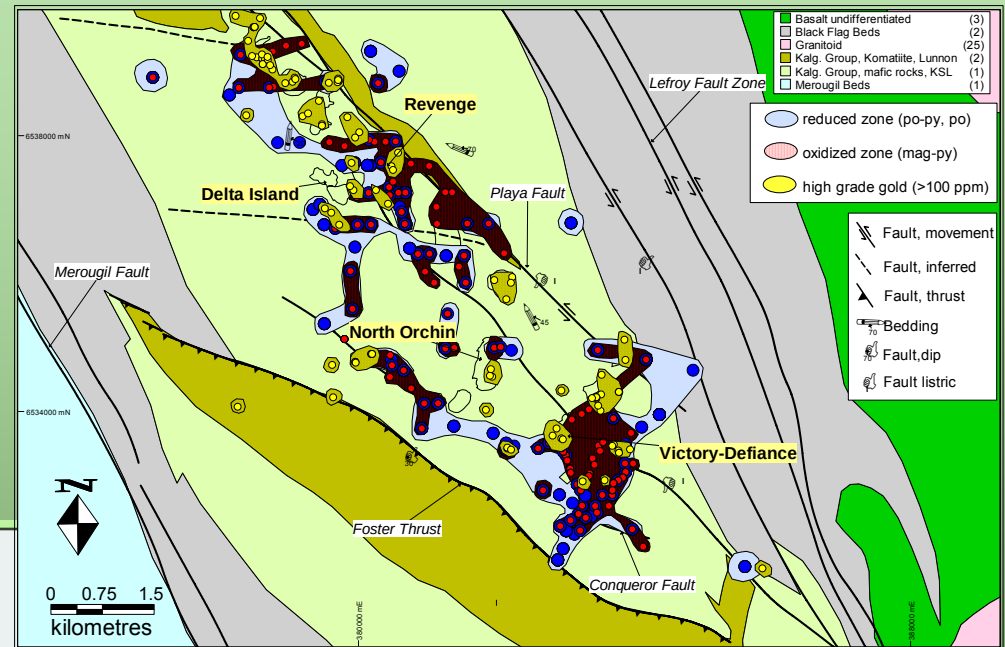
¹ Centre for Global Metallogeny, UWA

² CSIRO, Division of Exploration and Mining

³ St. Ives Gold Mining Company Pty Ltd

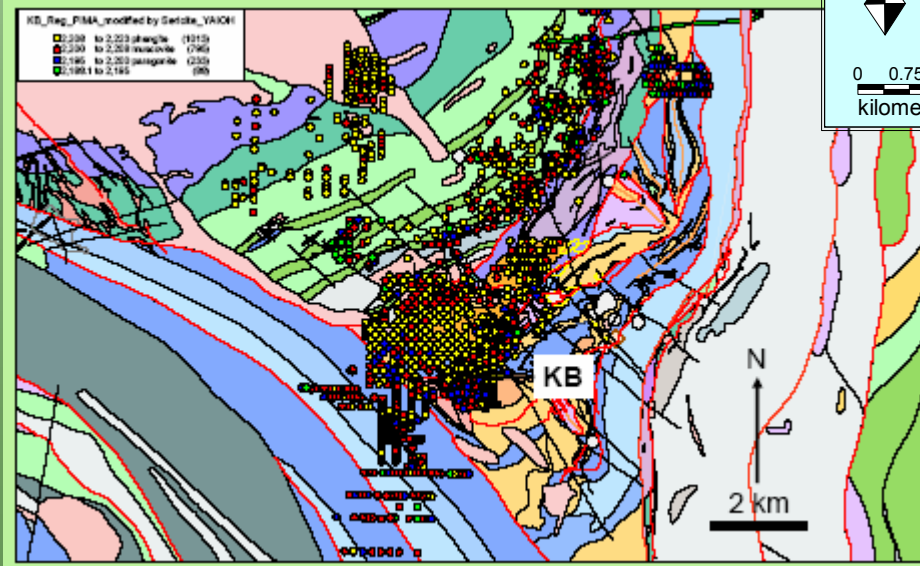


Alteration Zonation

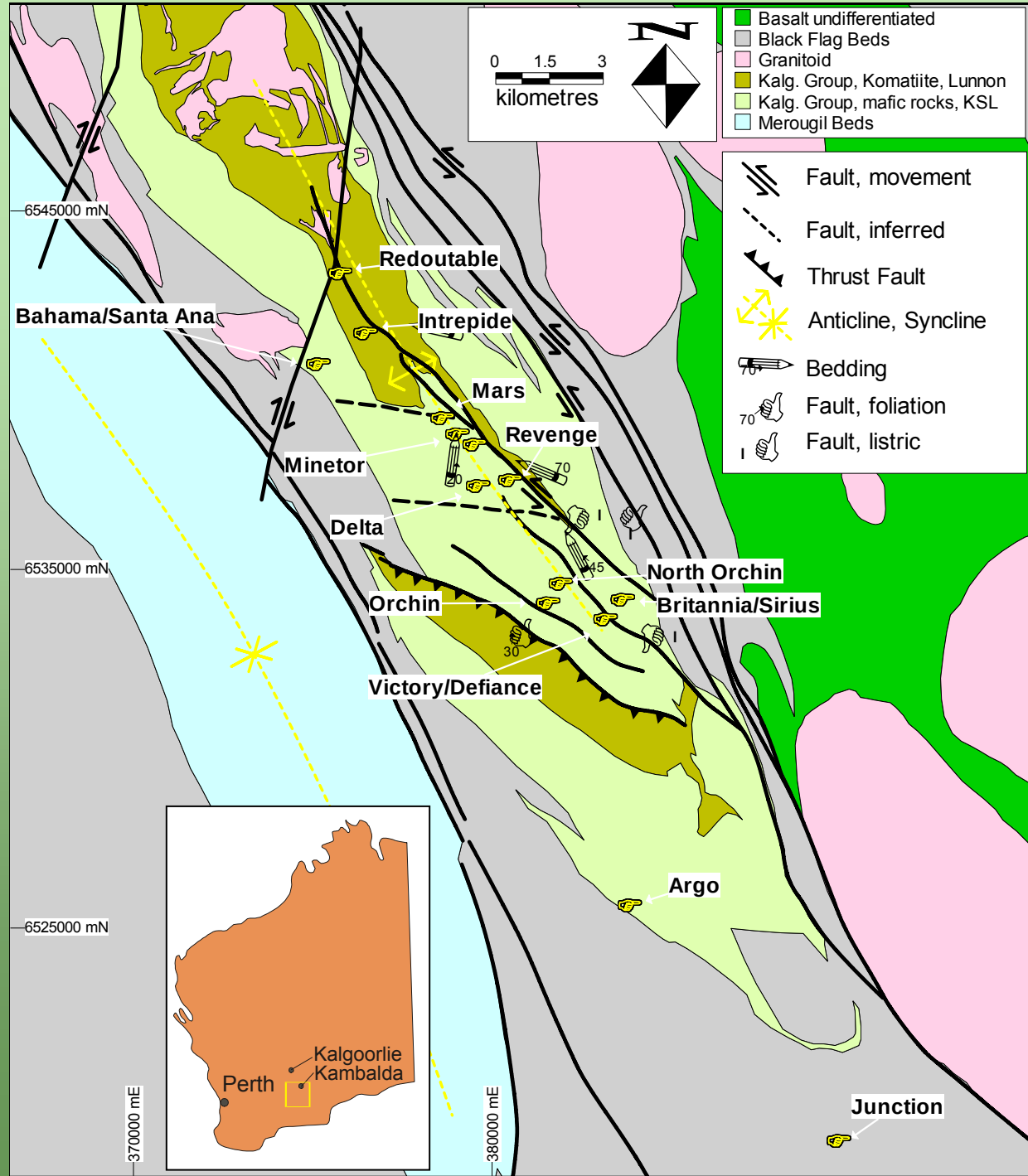


St. Ives

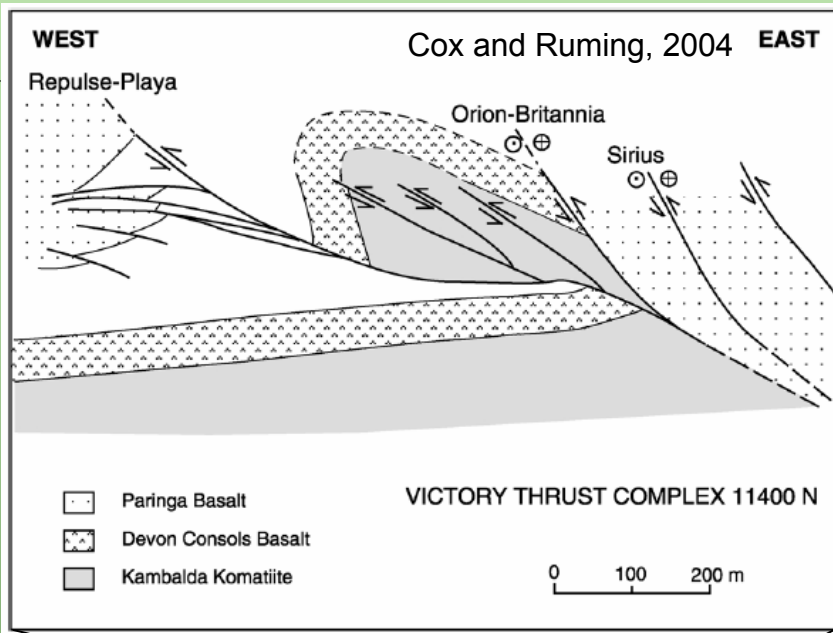
Kanowna Belle



Geological map of the St. Ives gold camp



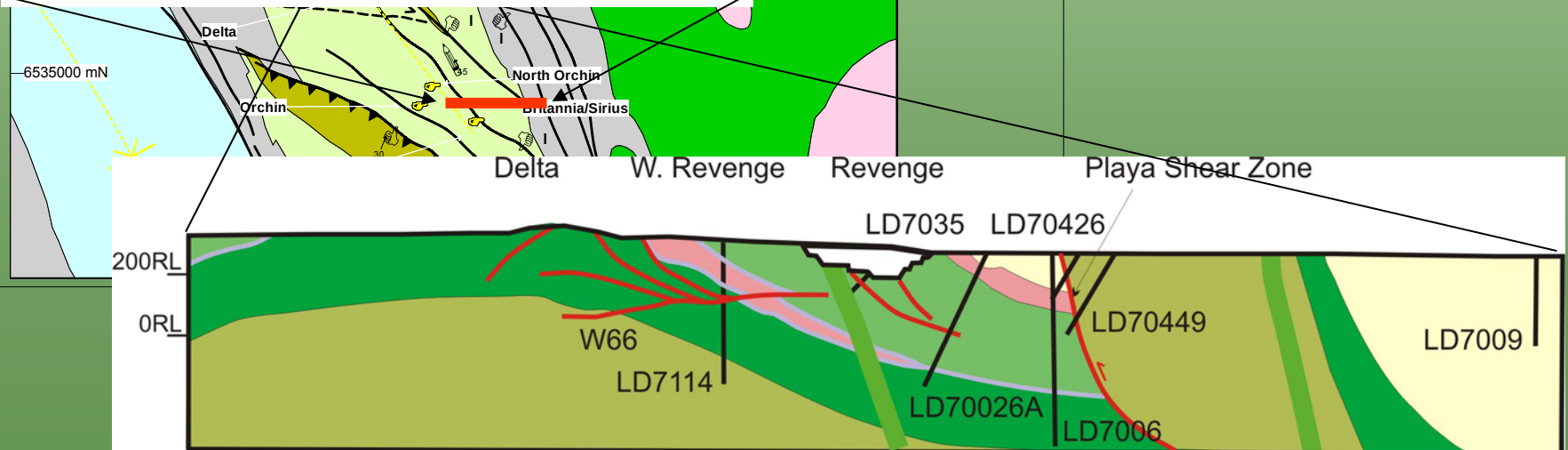
Structure – control on Au



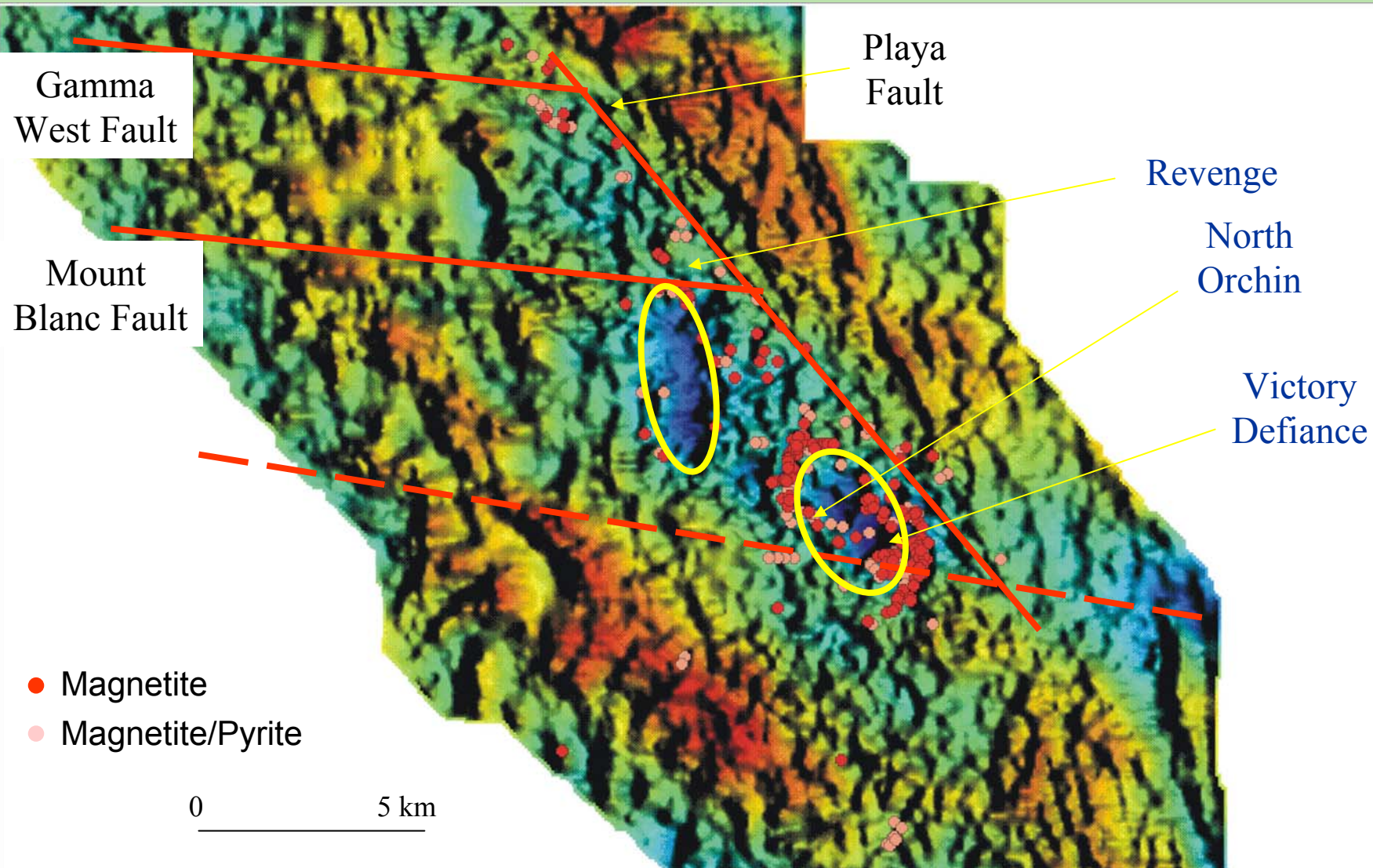
undifferentiated
lag Beds
id
group, Komatiite, Lunnon
group, mafic rocks, KSL
gil Beds

ovement
ferred
fault
e, Syncline
liation
tric

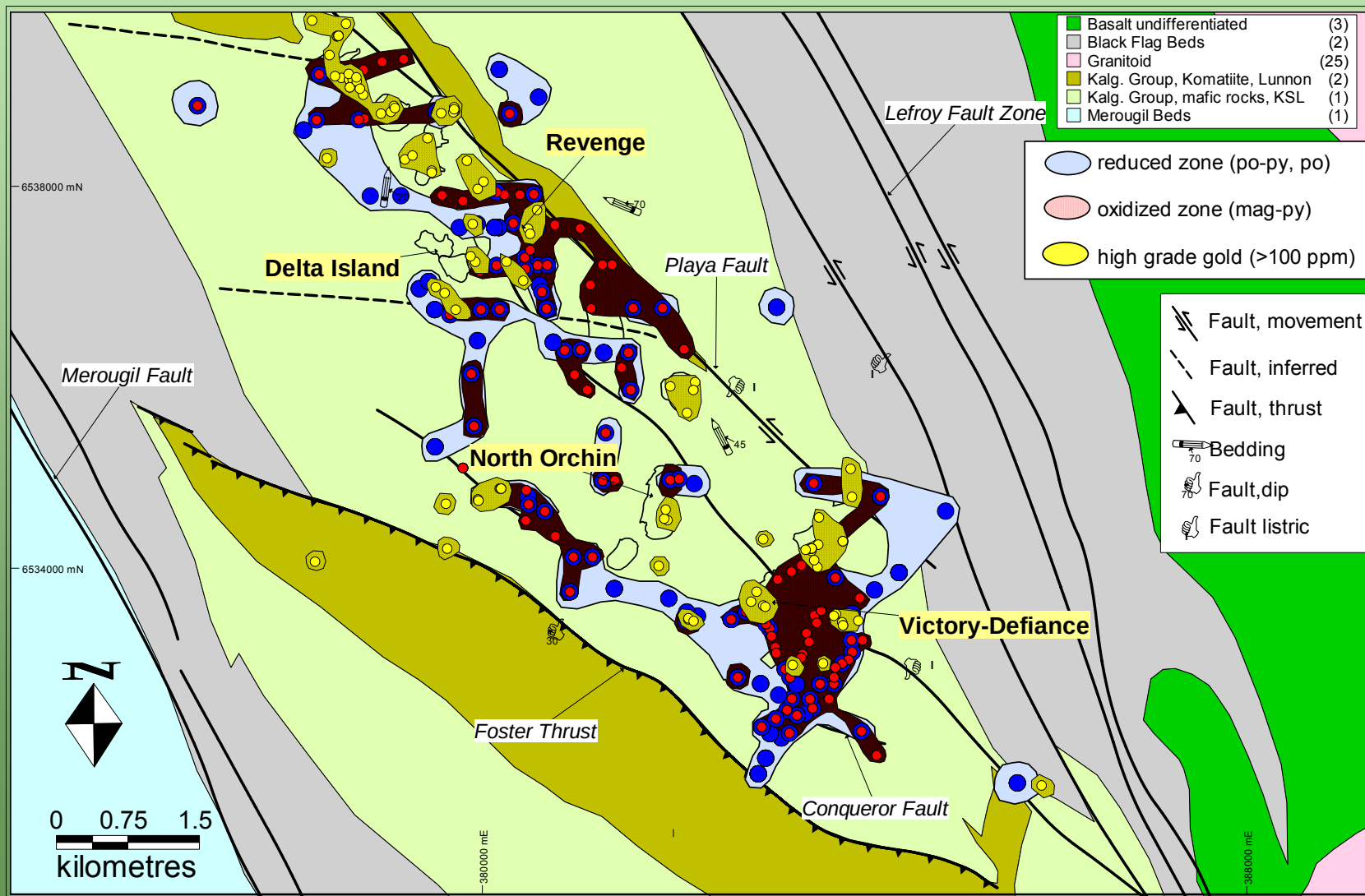
- First-order structure: Lefroy Fault
- Au controlled by contractional jog along second-order Playa Fault
- Au hosted in third- and fourth-order oblique- to reverse faults (Repulse, NO1, W66)



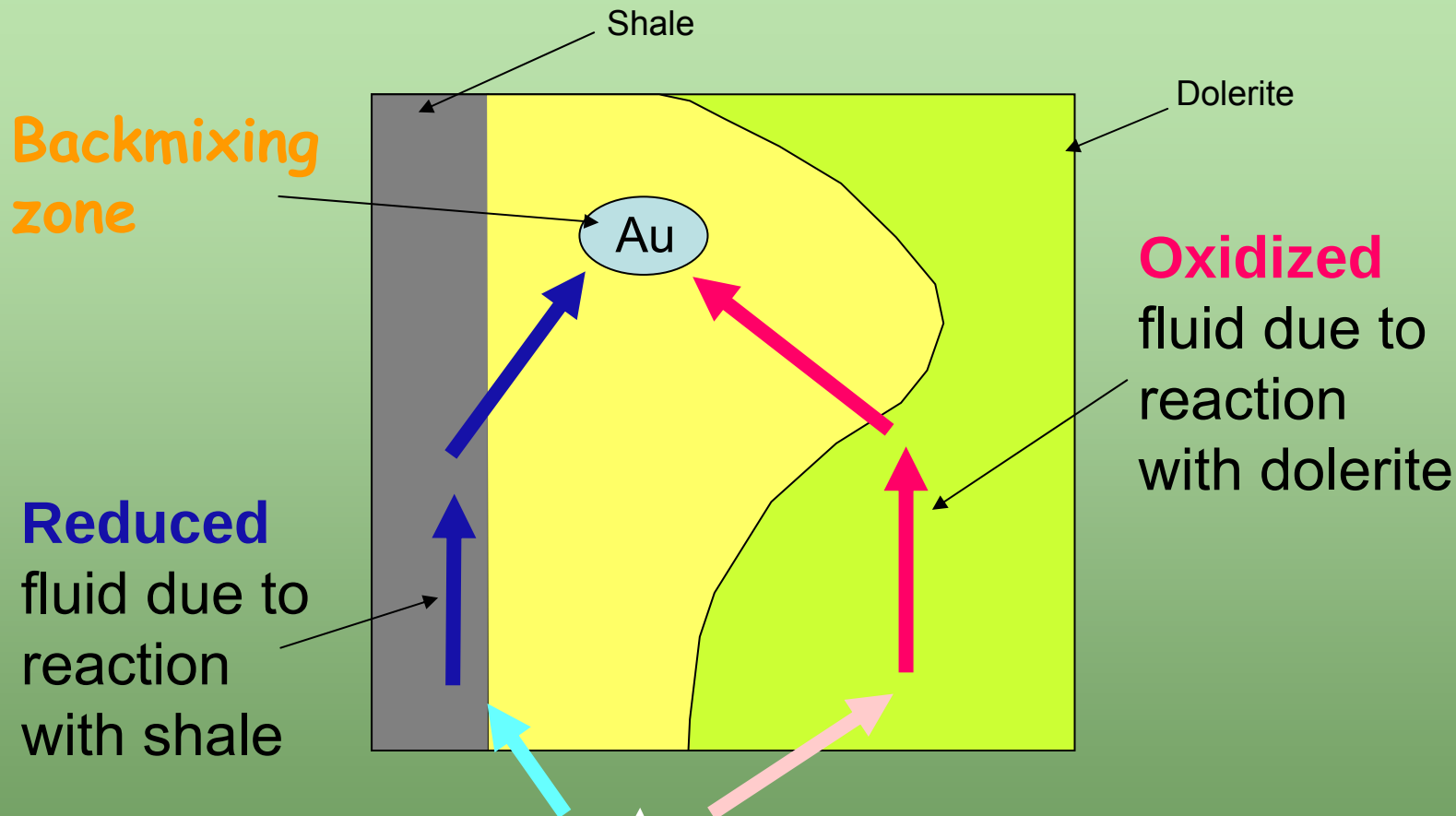
Camp-scale redox variations



Camp Scale Redox Variations – Mafic Rocks



Trapsite Back Mixing Model

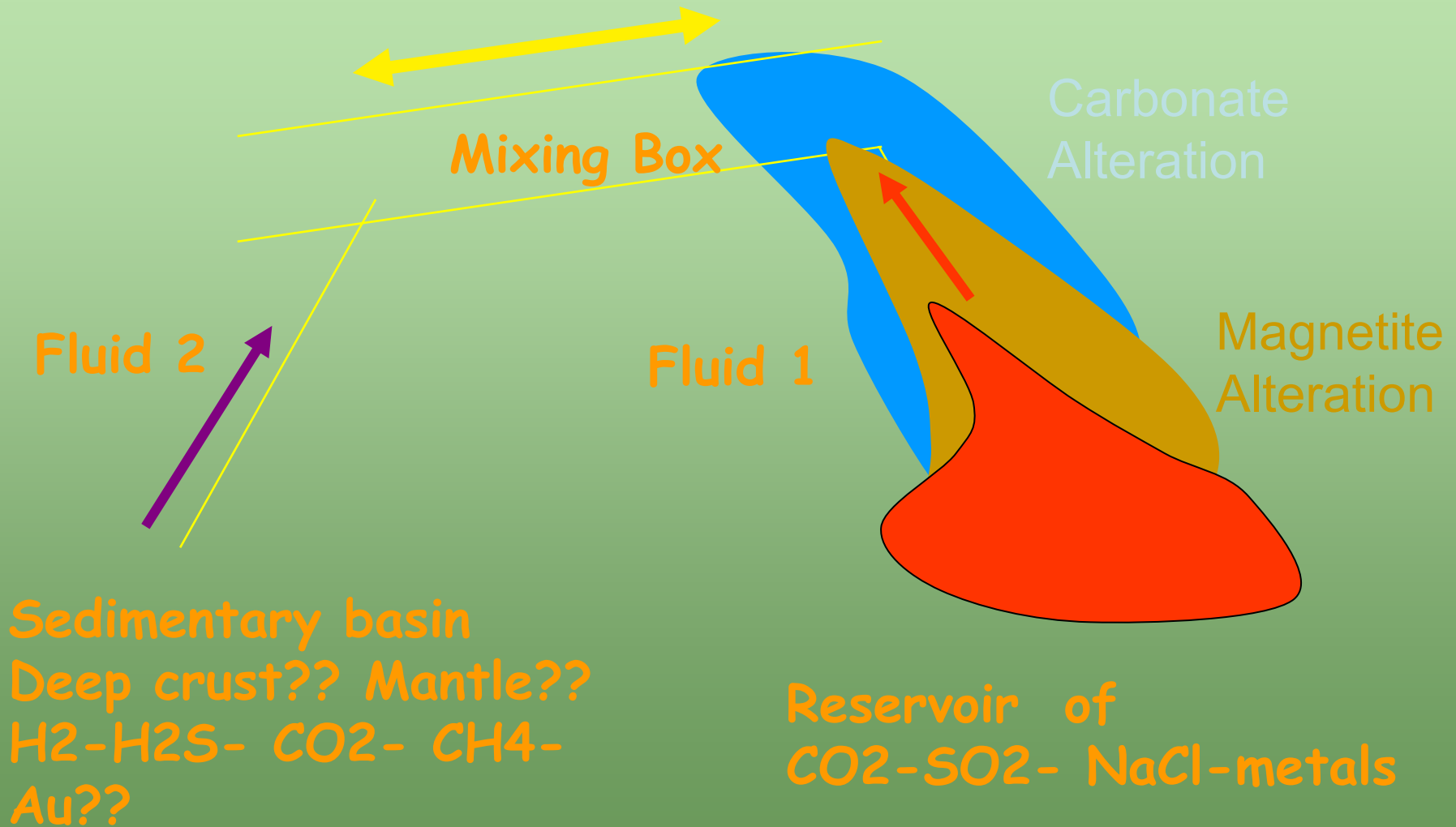


One fluid: $H_2O-CO_2 \pm CH_4-NaCl$

Single Fluid Model

e.g., Uemoto et al., 2002

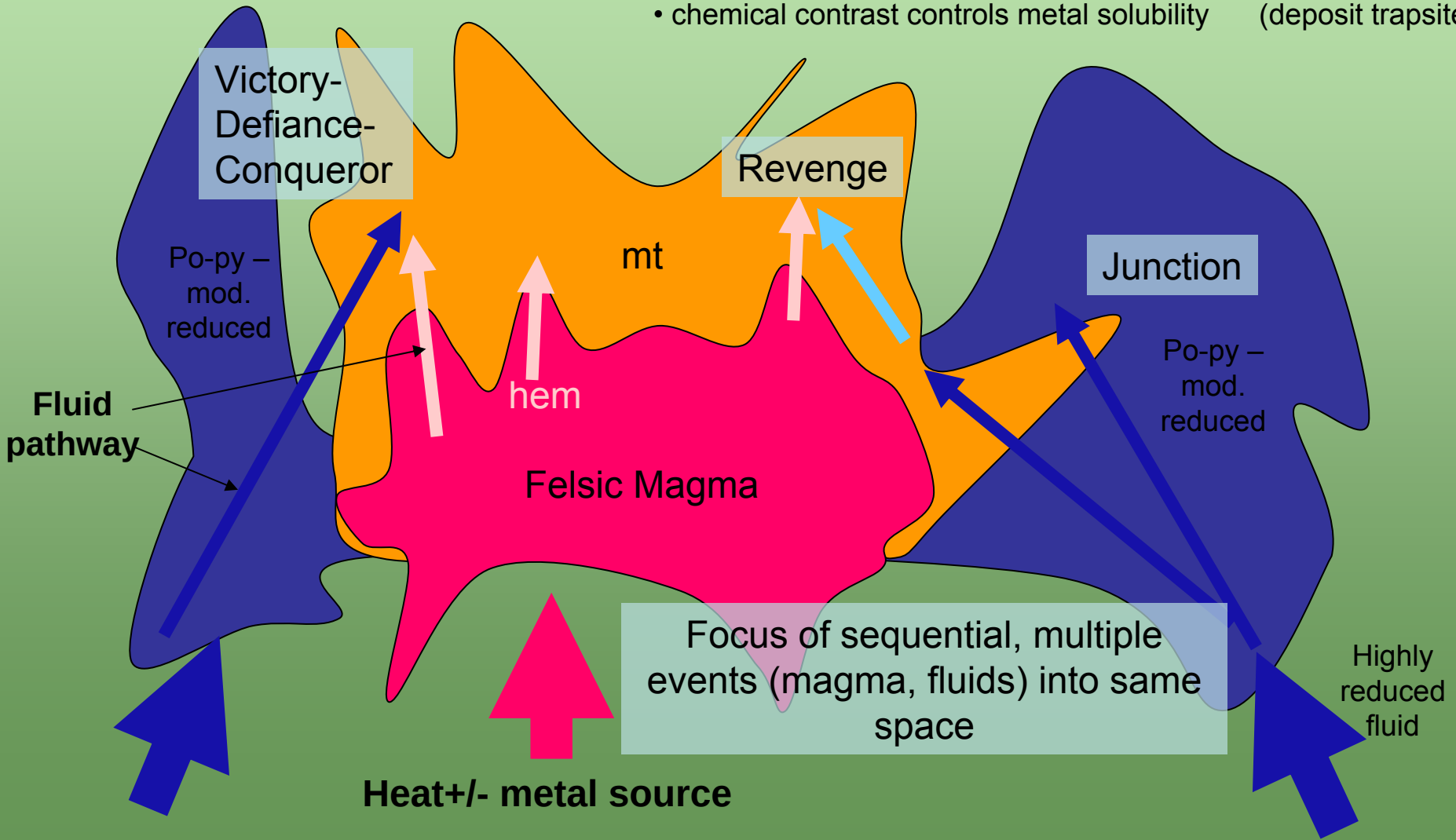
Mixing Model



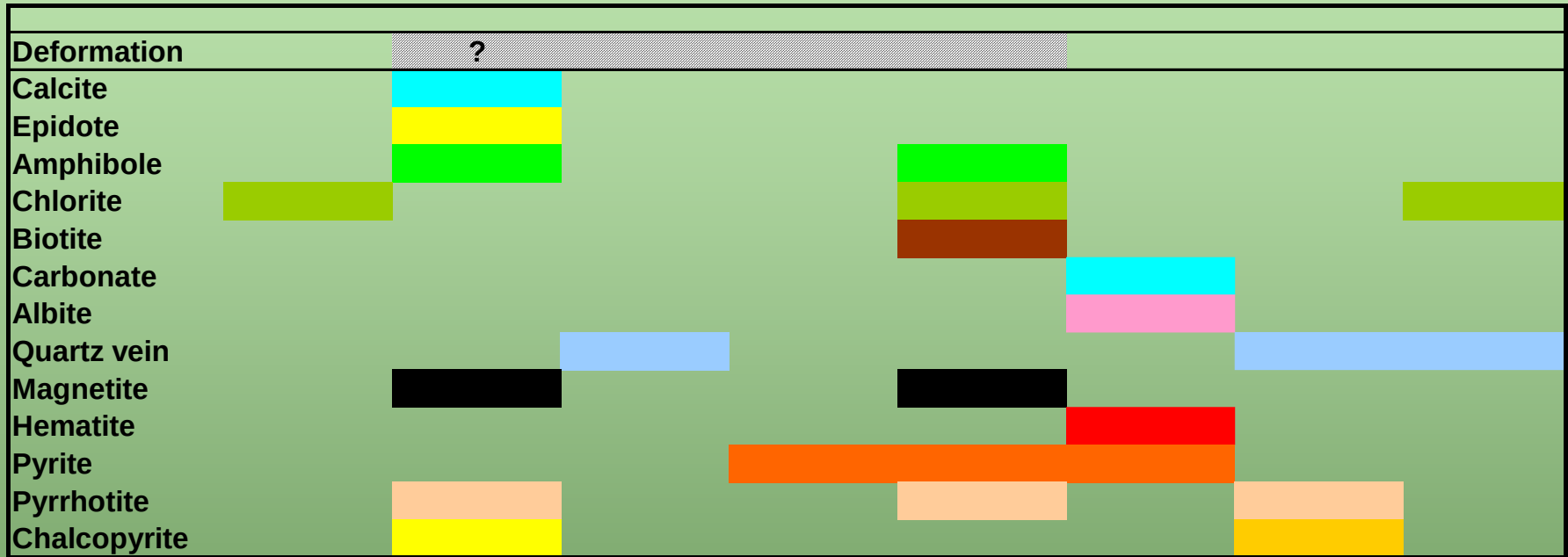
Multifluid Model

- contrasting fluids
- multiple events in same space
- modified by wallrock reaction and mixing
- chemical contrast controls metal solubility

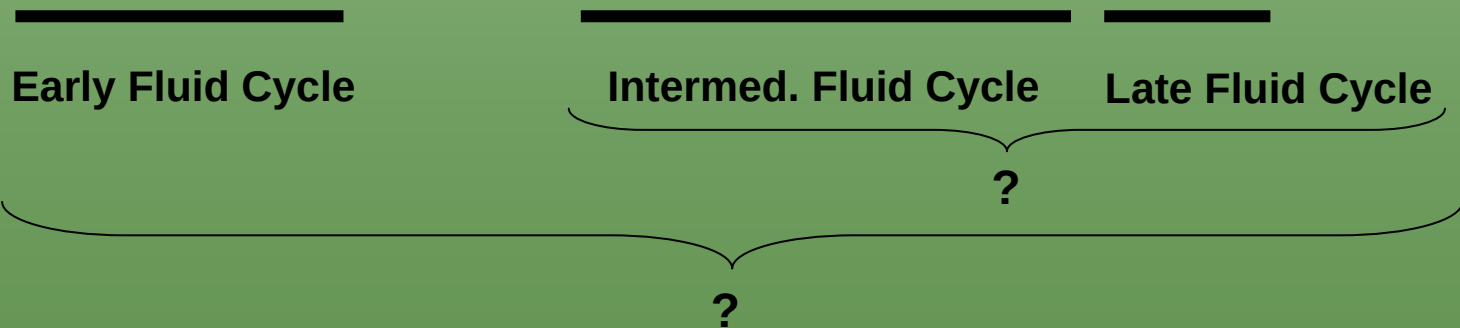
(metal source)
(camp-trapsite)
(deposit trapsite)
(deposit trapsite)



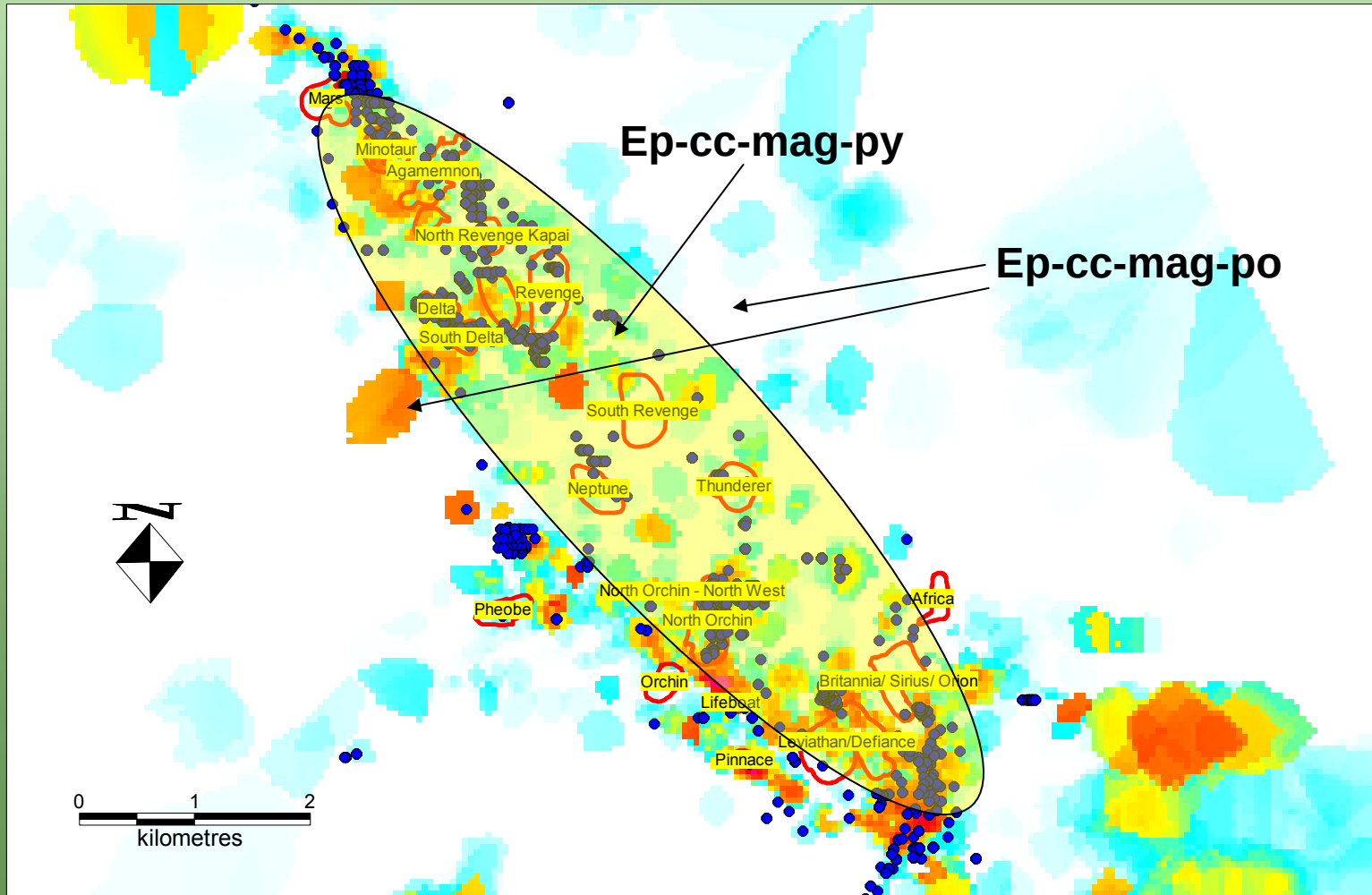
Relative timing of hydrothermal alteration assemblages



Au

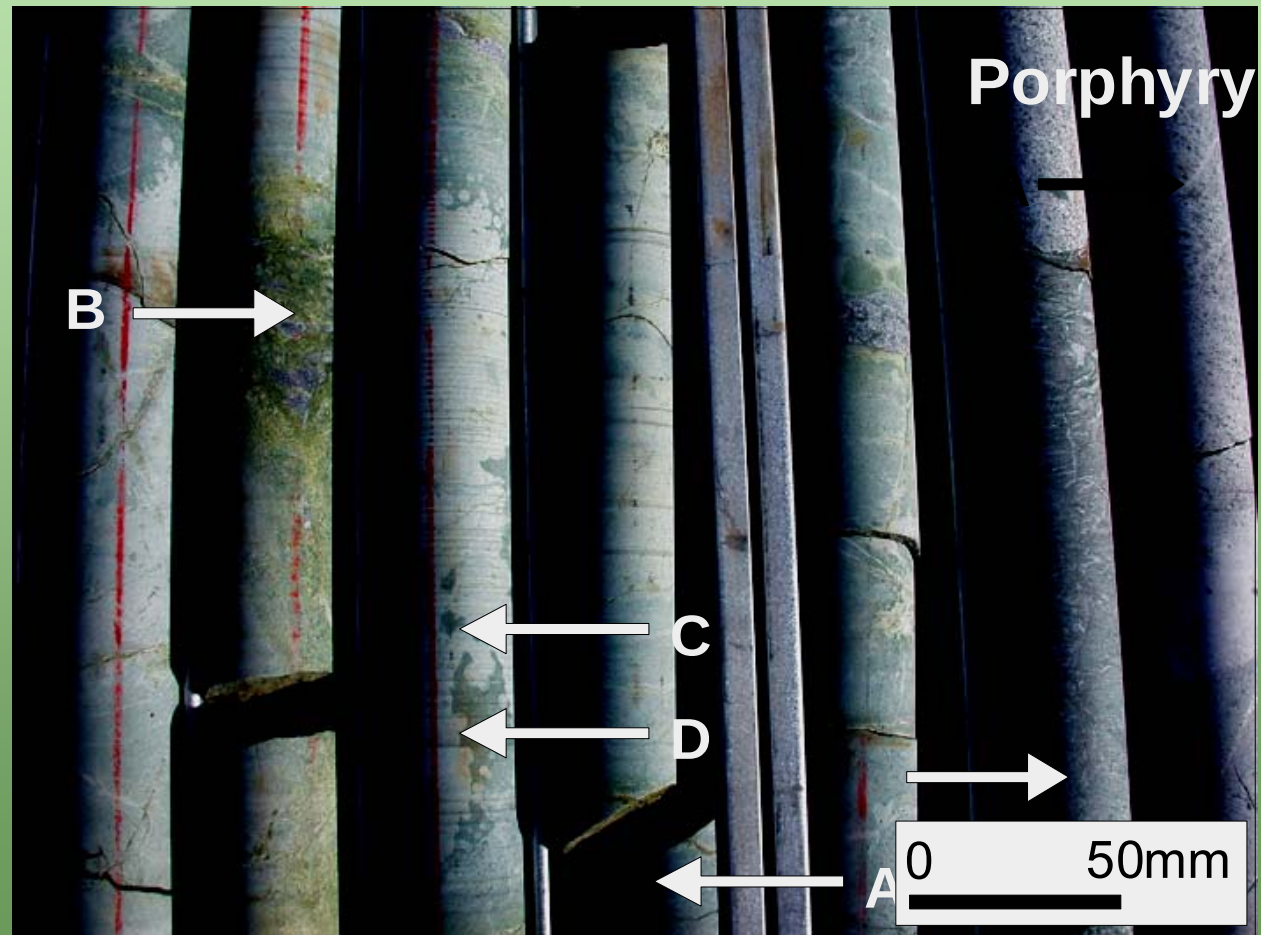


Epidote distribution camp scale



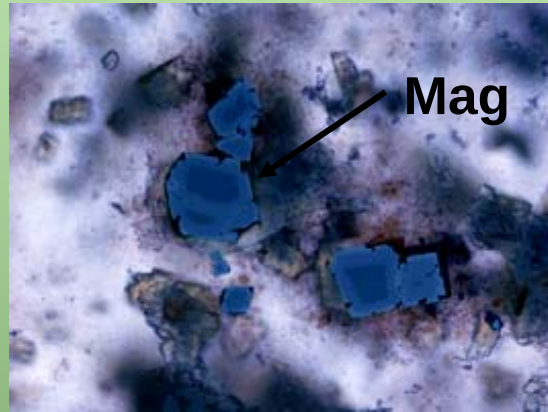
Epidote porphyry relationship

- Hbl-bt porphyry
- distinct ep-cc-mag alteration
- $\pm$ py $\pm$ chpy
- qtz veins
- up to 5m
- locally overprinted by foliation



Early fluid cycle

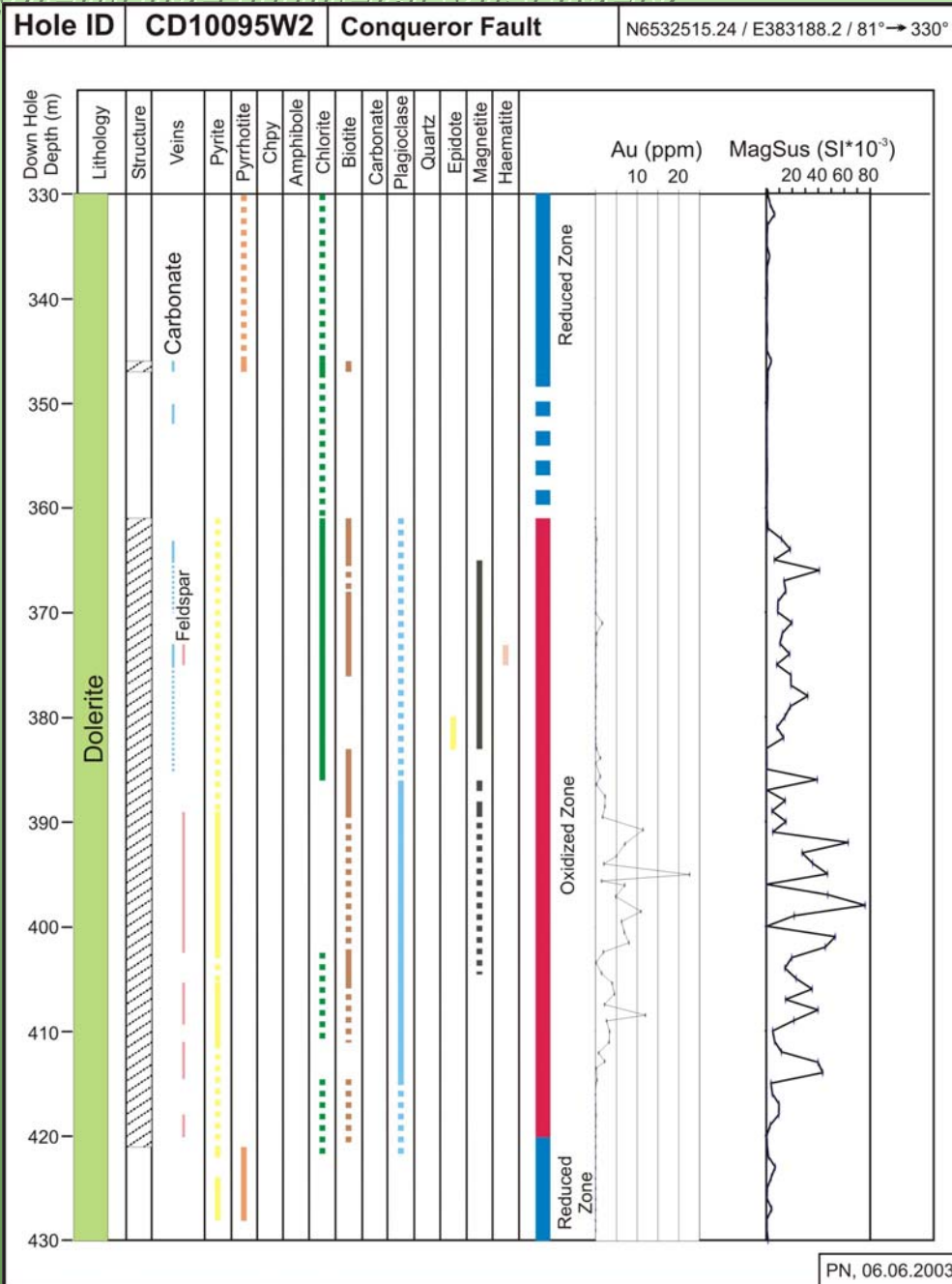
Qtz-cc-hbl-py $\pm$ chpy



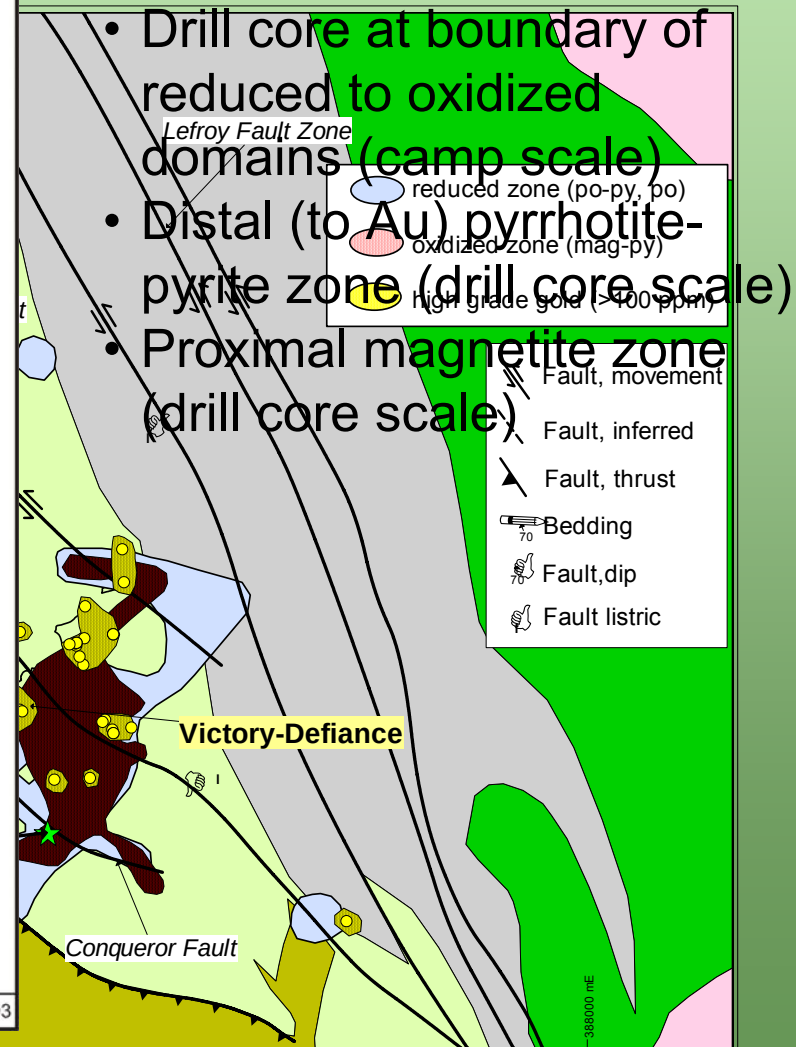
Cc-qtz-hbl-chpy $\pm$ py



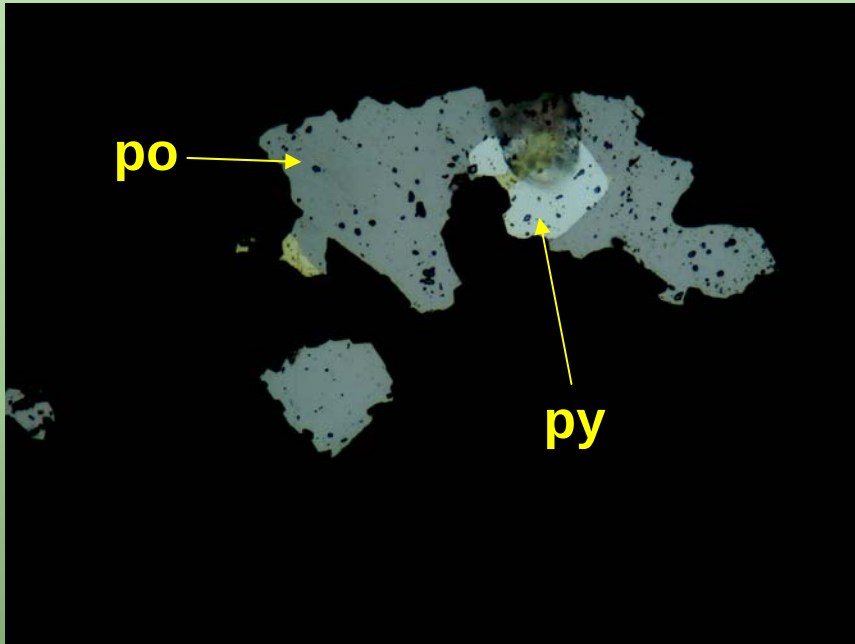
1. Hbl
2. Ep-Mag1
3. Cc-qtz-Mag1
4. Qtz-cc



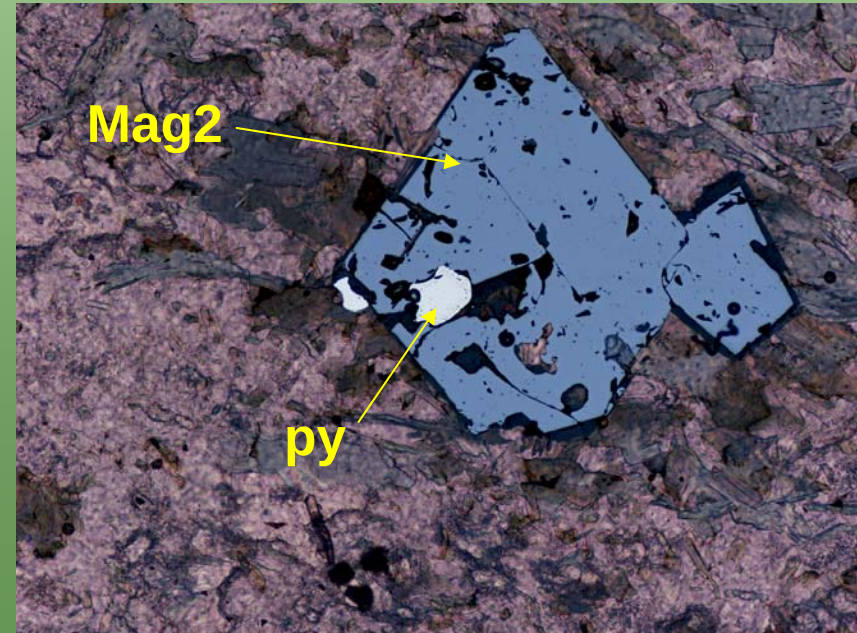
Fluid Cycle



Redox minerals



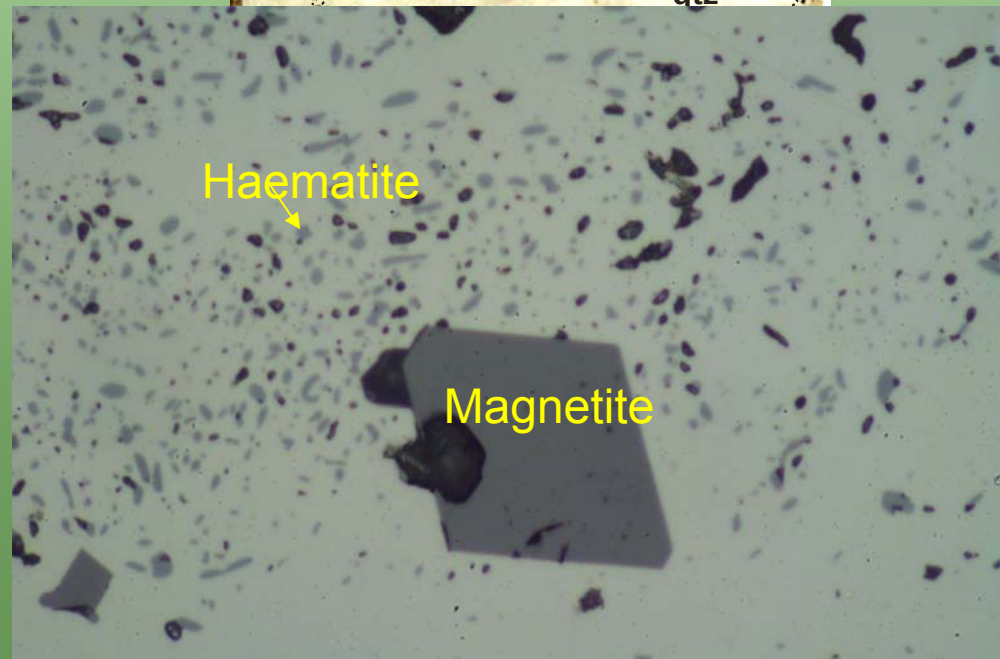
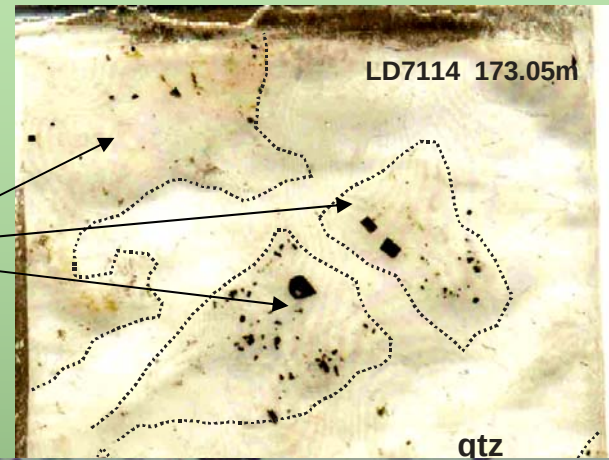
Both magnetite and pyrrhotite
overprint earlier pyrite



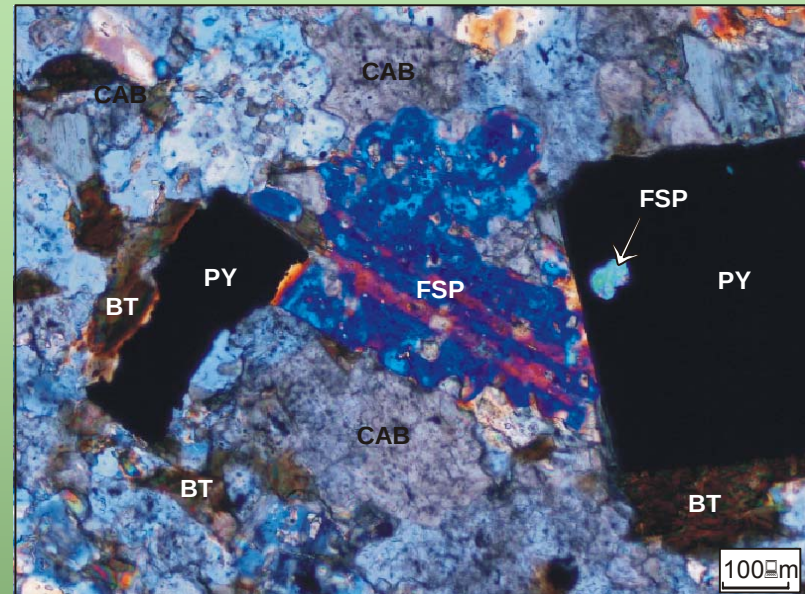
Feldspar-carbonate-quartz



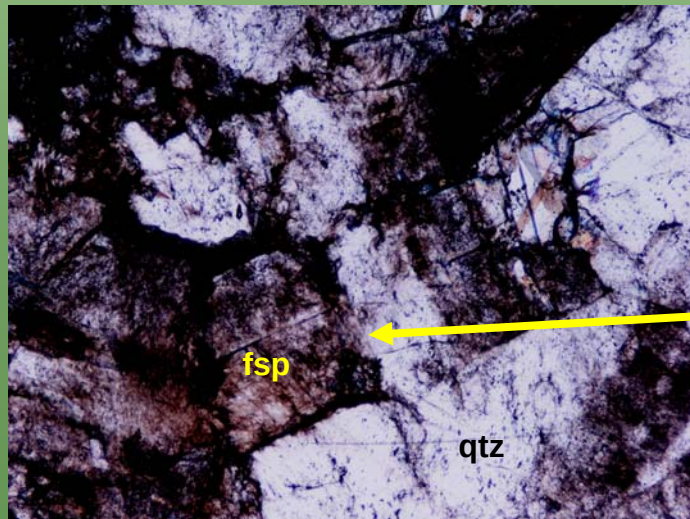
sp-carb-py



Feldspar-carbonate-quartz texture

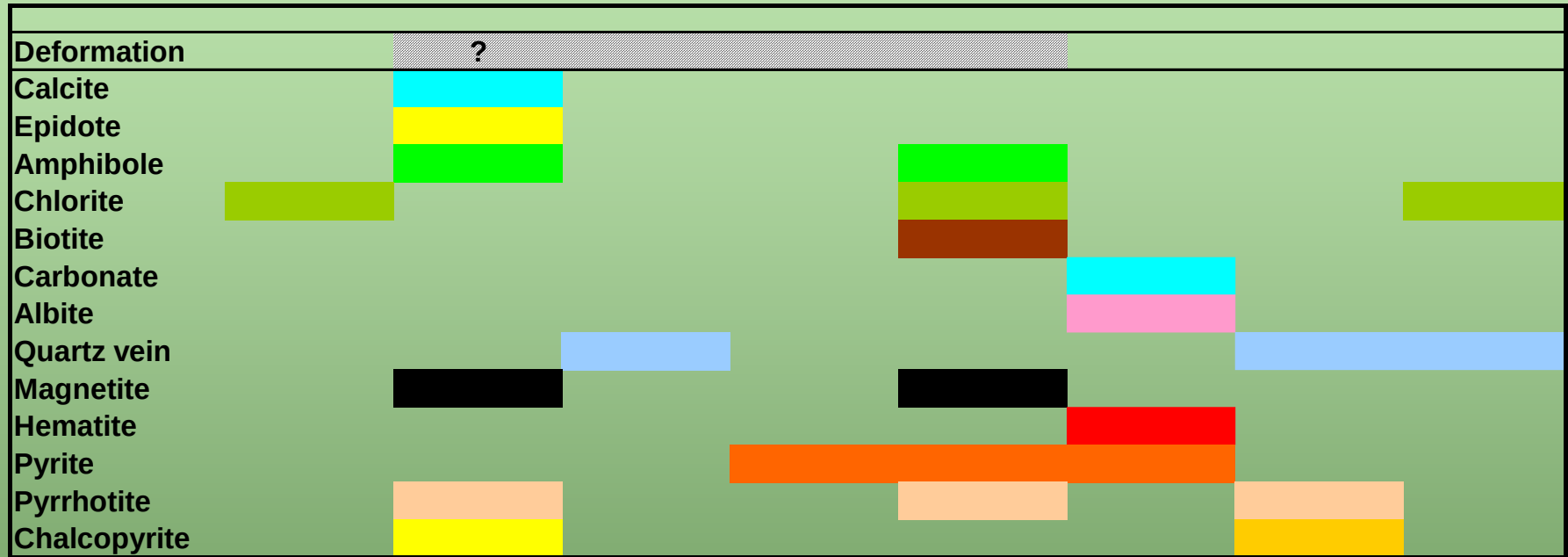


1. Fsp-py
2. Carb
3. Qtz (Late Cycle?)

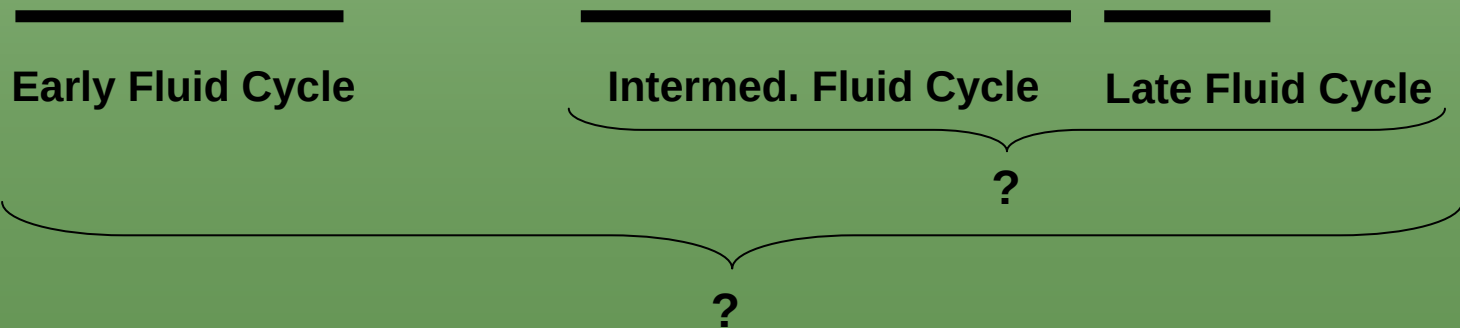


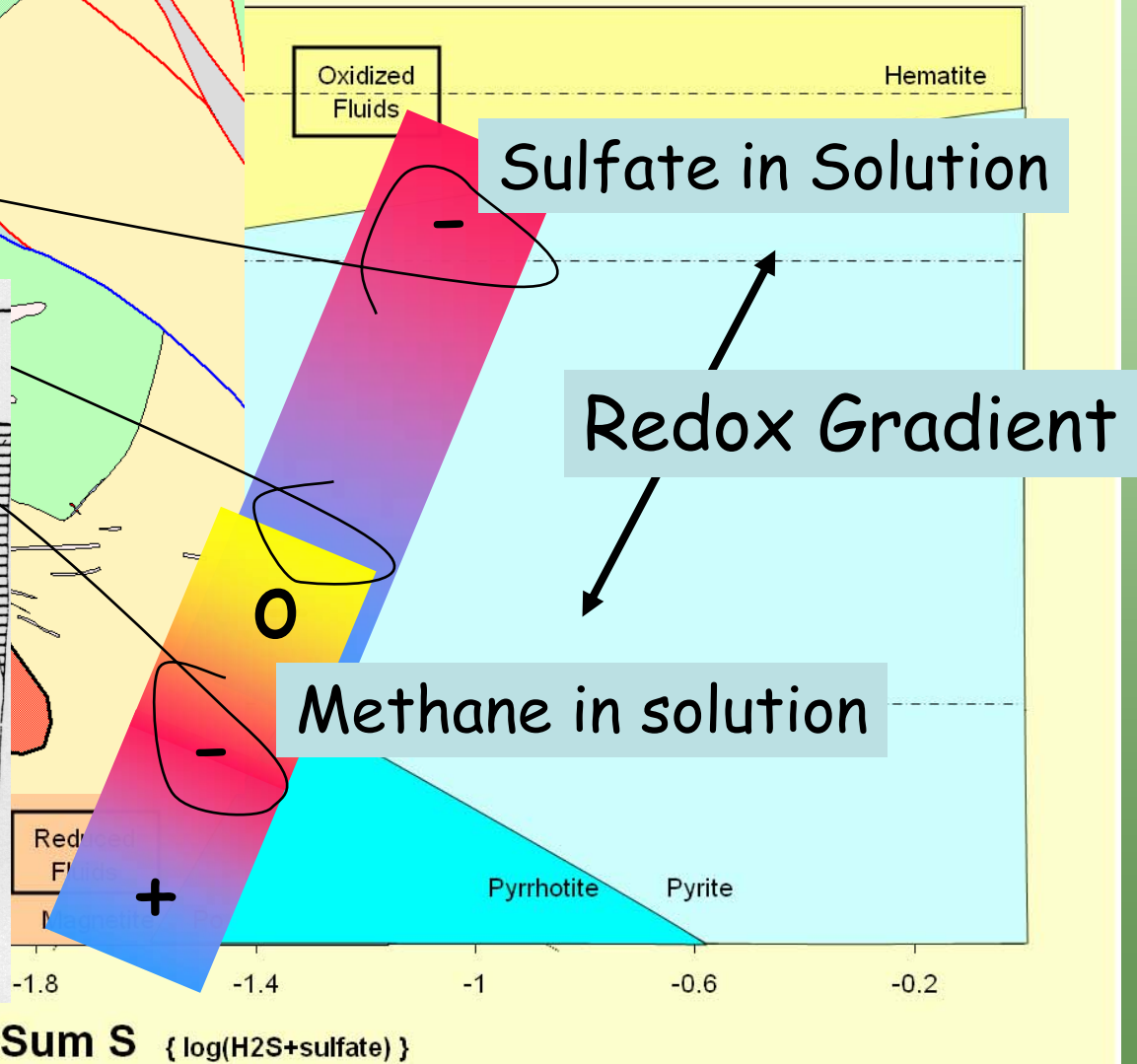
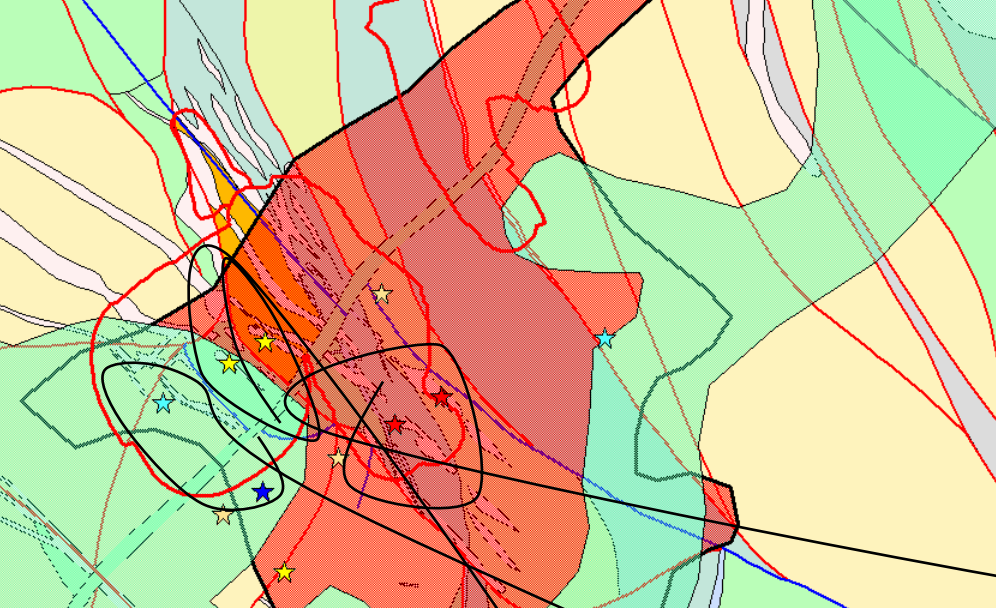
Dissolution of fsp by qtz

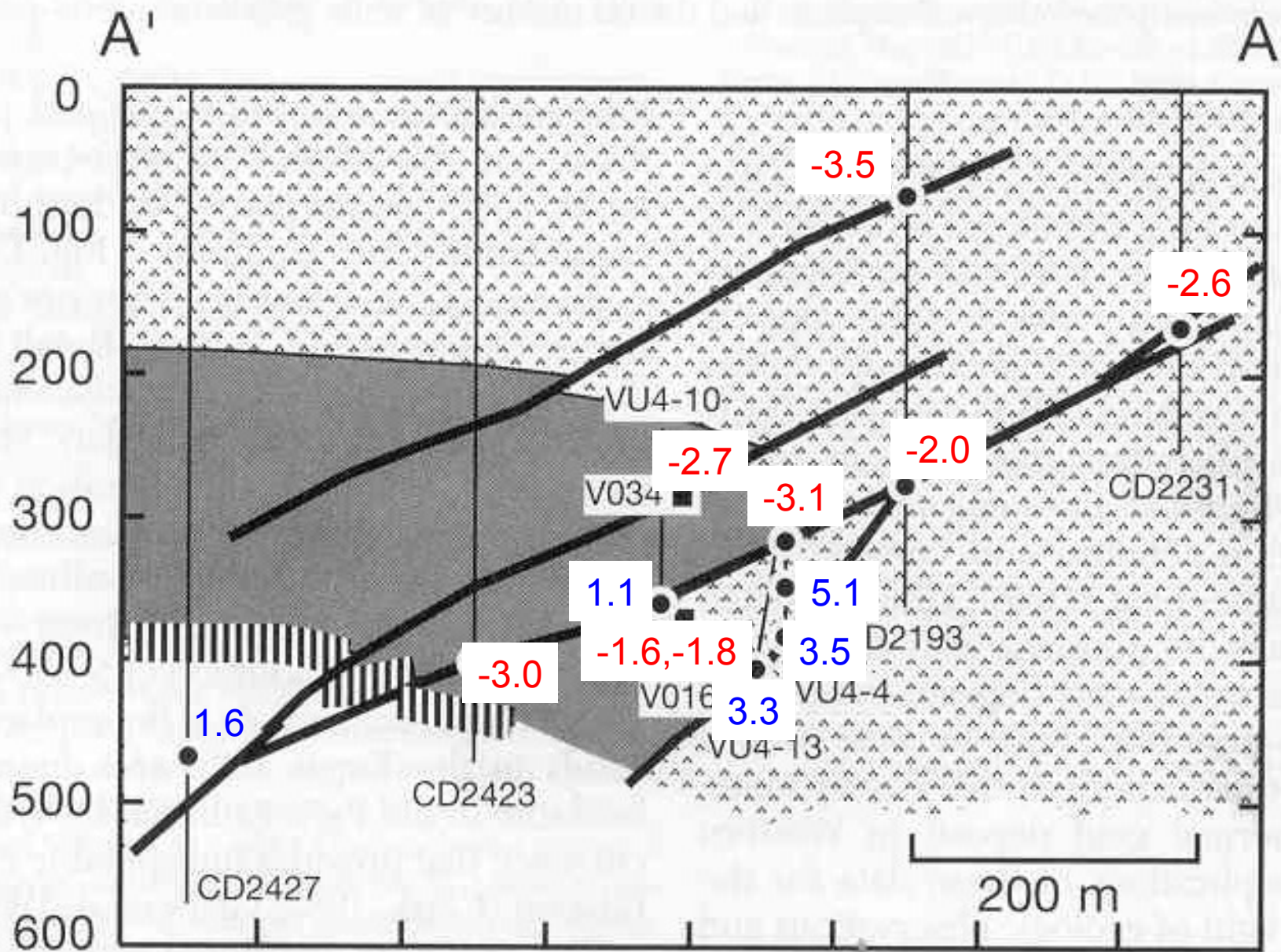
Relative timing of hydrothermal alteration assemblages



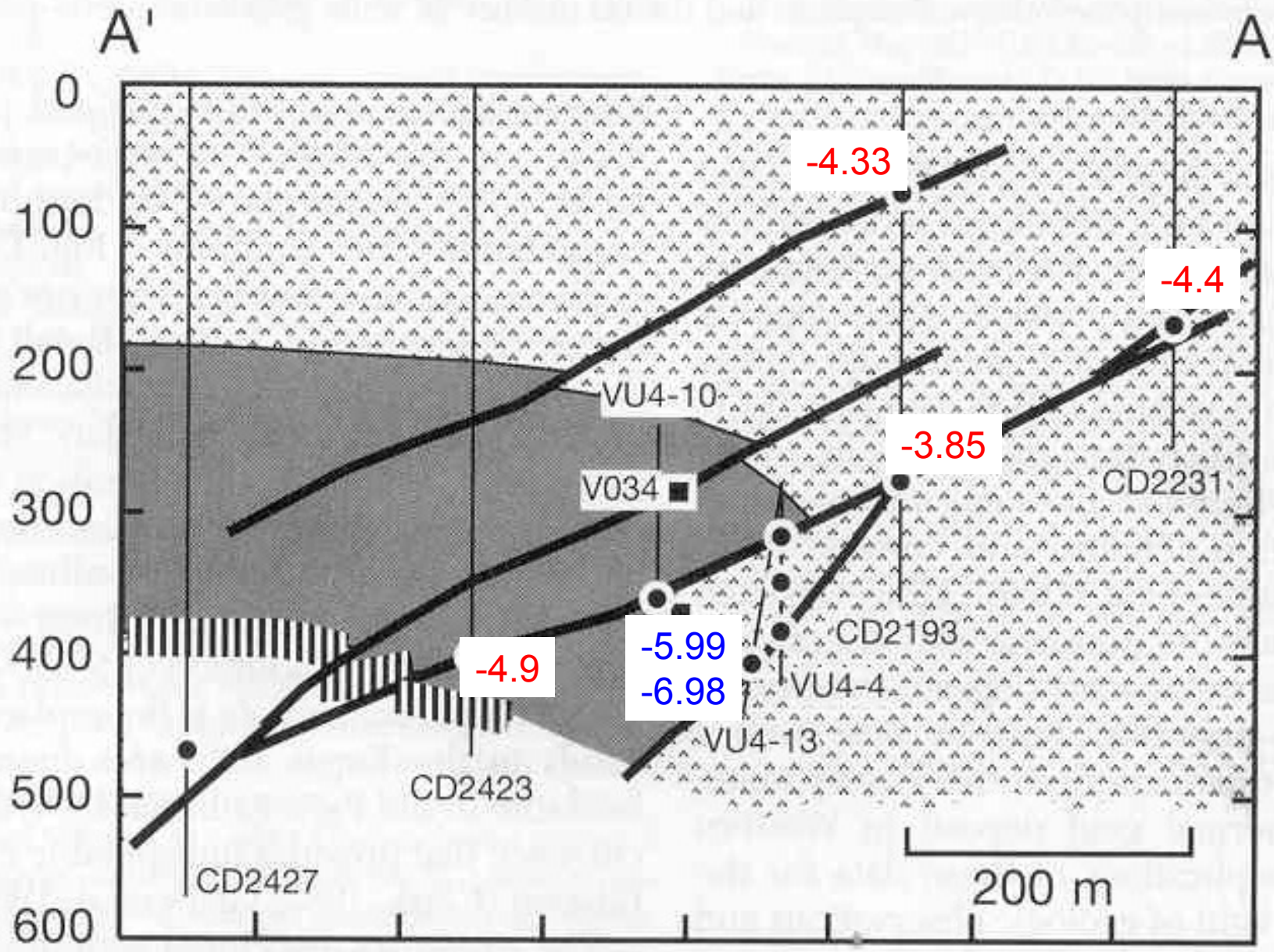
Au





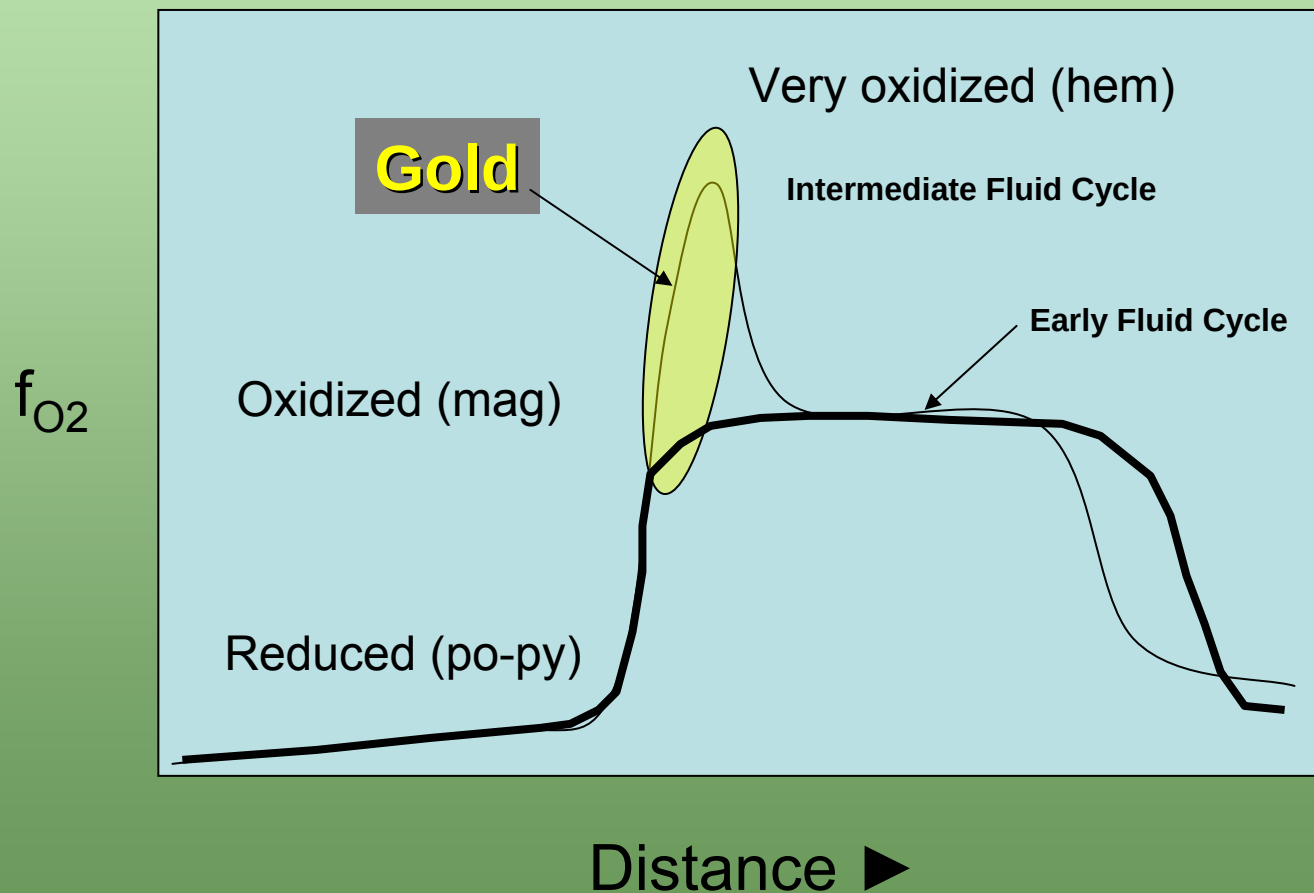


Del 34 S in pyrite



Del ^{13}C in carbonate

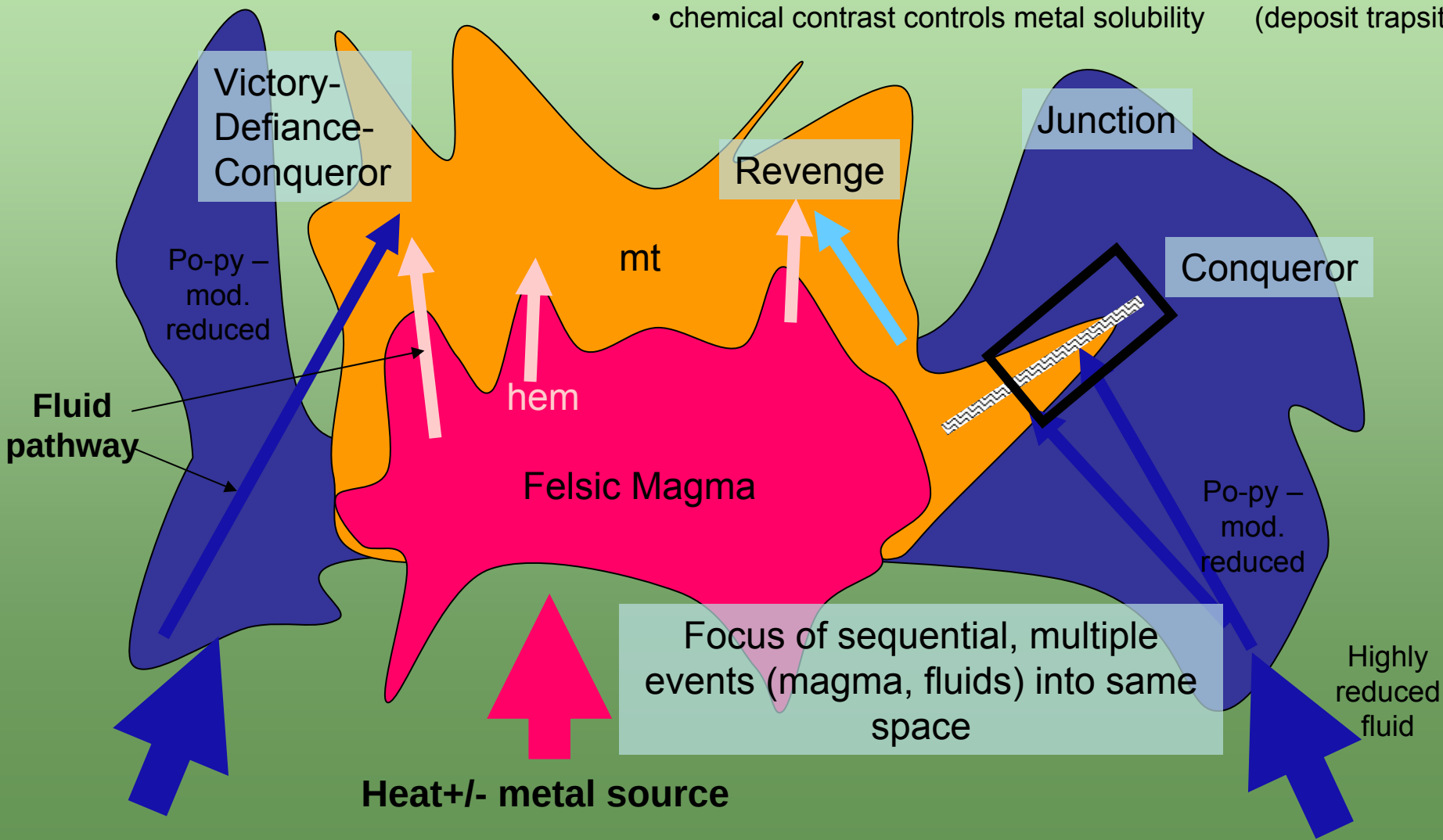
Redox - gradient spatial



Multifluid Model

- contrasting fluids
- multiple events in same space
- modified by wallrock reaction and mixing
- chemical contrast controls metal solubility

(metal source)
(camp-trapsite)
(deposit trapsite)
(deposit trapsite)



P-T-x-fO₂-t of hydrothermal end-member fluids and fluid evolution in the St. Ives gold camp

Klaus Petersen, Peter Neumayr, Steffen, Hagemann

Centre for Global Metallogeny, The University of Western Australia

Aims

- Determine fluid end-member and evolution in the hydrothermal alteration systems

Present Knowledge of the fluid cycles

- Three Systems:
 - Epidote dominant equivalent to “**early**” fluid cycle
 - Feldspar dominant (Gold) equivalent to “**intermediate**” fluid cycle
 - Quartz dominant equivalent to “**late**” fluid cycle

Philosophy

- Detailed textural analysis to determine **relative timing** of minerals and characteristic **fluid inclusion assemblages**
- Fluid inclusion microthermometry in **all main-stage hydrothermal alteration minerals** (eg. epidote, feldspar, carbonate)

Early Fluid Cycle

**Epidote-magnetite±quartz-
chalcopyrite-pyrite**

Quartz 1: primary carbonic, aqueous,
aqueous carbonic FI with daughter crystals

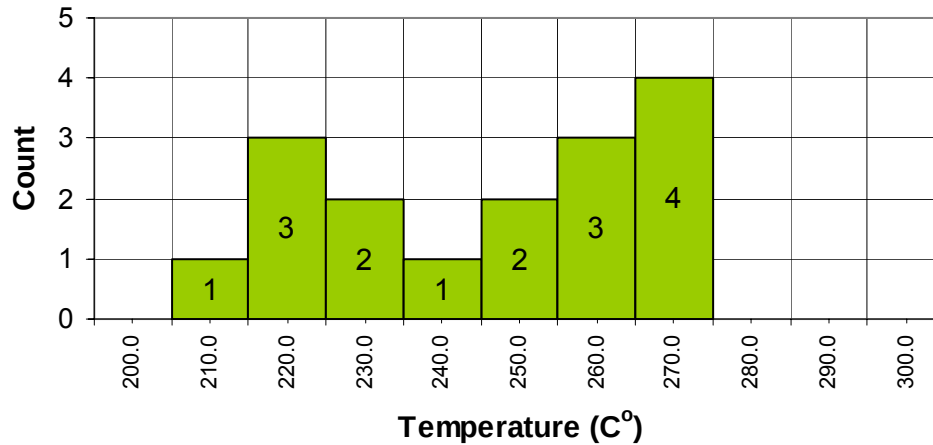
Quartz/carbonate 2: primary carbonic, aqueous,
aqueous carbonic FI with daughter crystals

Epidote: primary aqueous FI

Quartz: primary aqueous FI



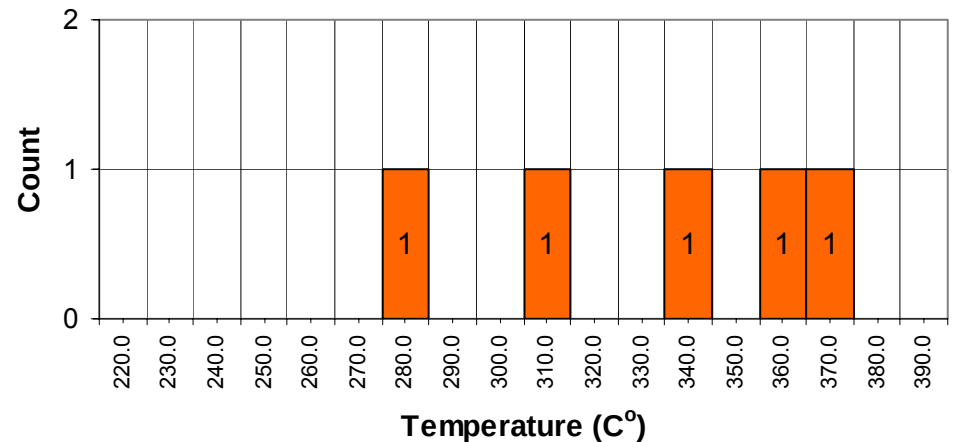
LD7113A/42.8m
Th_{total} on epidote



Early Fluid Cycle

**Epidote-magnetite±quartz-
chalcopyrite-pyrite**

LD7113A/42.8m
Th_{total} on quartz



Intermediate (Gold) Fluid Cycle

Feldspar-carbonate-pyrite $\pm$ Au

**Feldspar: primary
carbonic $\pm$ aqueous FI**

**Carbonate: primary
carbonic aqueous FI**

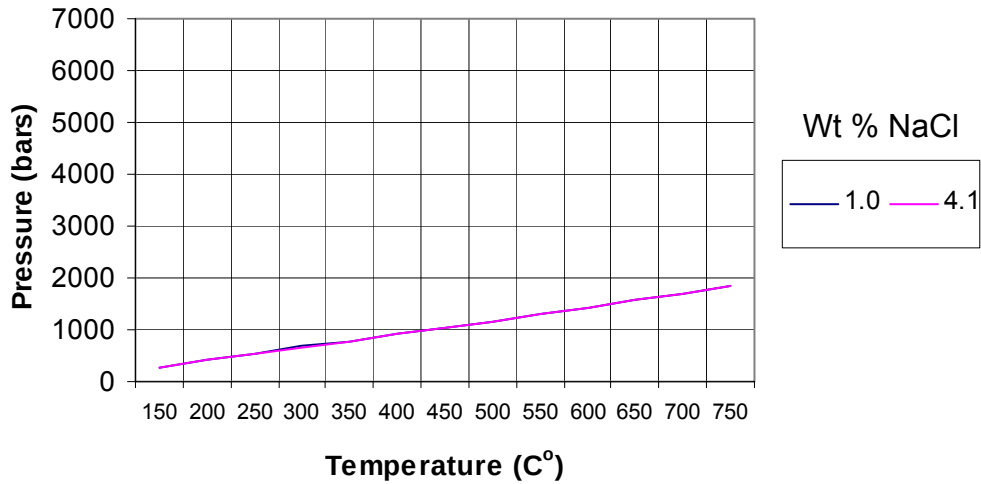
**Quartz 1: primary carbonic, aqueous,
aqueous carbonic FI with daughter crystals**

**Quartz/carbonate 2: primary carbonic, aqueous,
aqueous carbonic FI with daughter crystals**



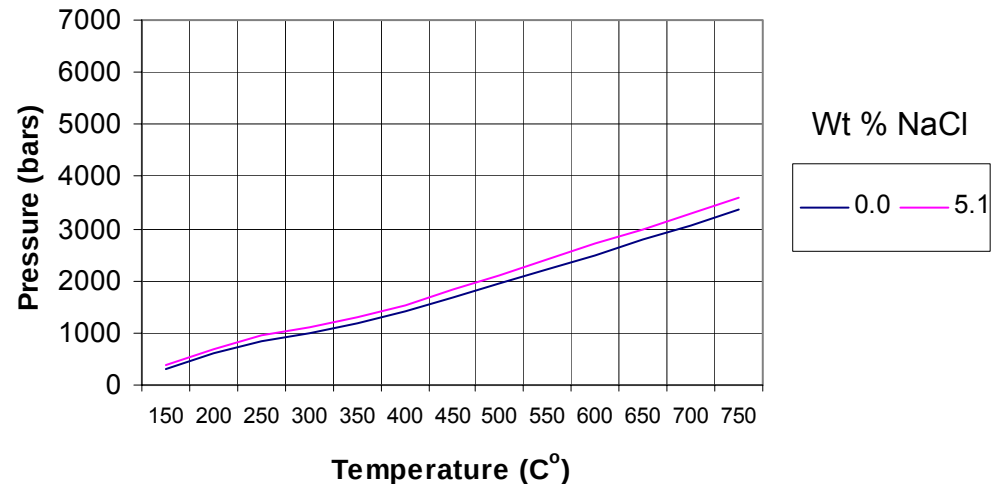
Intermediate (Gold) Fluid Cycle

Carbonic-aqueous FI in **Feldspar**



Feldspar-carbonate-pyrite±Au

Carbonic-aqueous FI in **Carbonate**



Late Fluid Cycle

Quartz±carbonate

Feldspar: primary carbonic±aqueous FI

Carbonate: primary carbonic aqueous FI

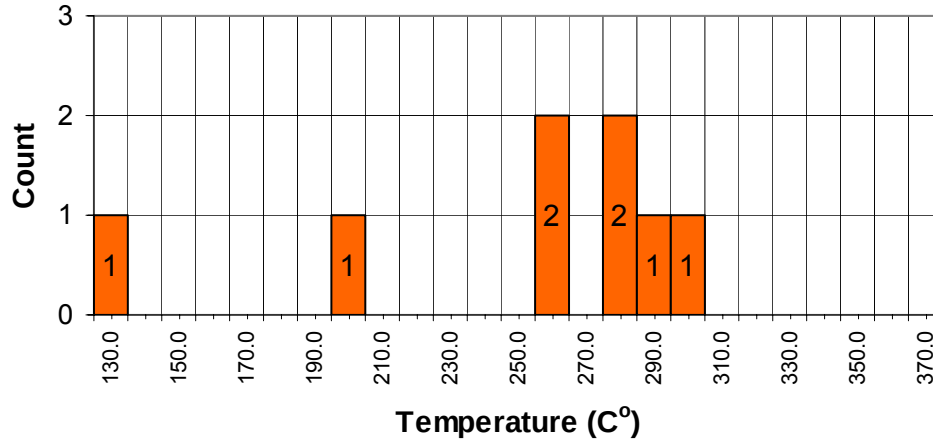
Quartz 1: primary carbonic, aqueous, aqueous carbonic FI with daughter crystals

Quartz/carbonate 2: primary carbonic, aqueous, aqueous carbonic FI with daughter crystals



LD7113A/42.8m

Th_{total} on quartz of the **Late Cycle**

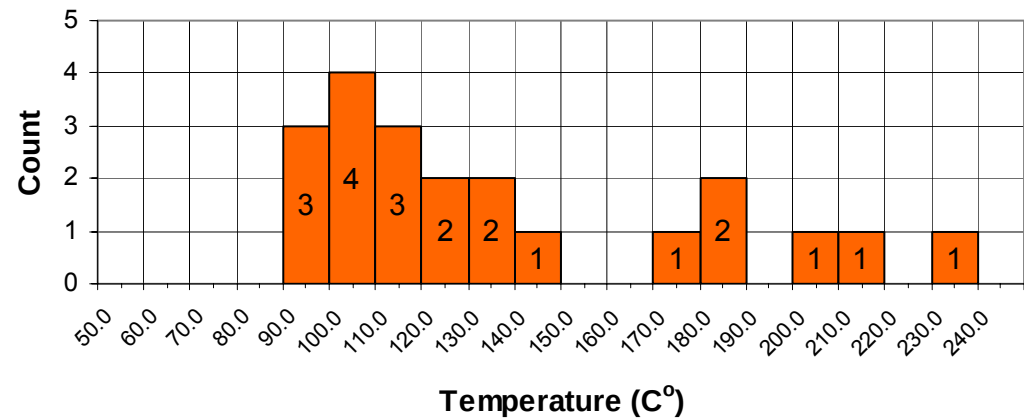


Late Fluid Cycle

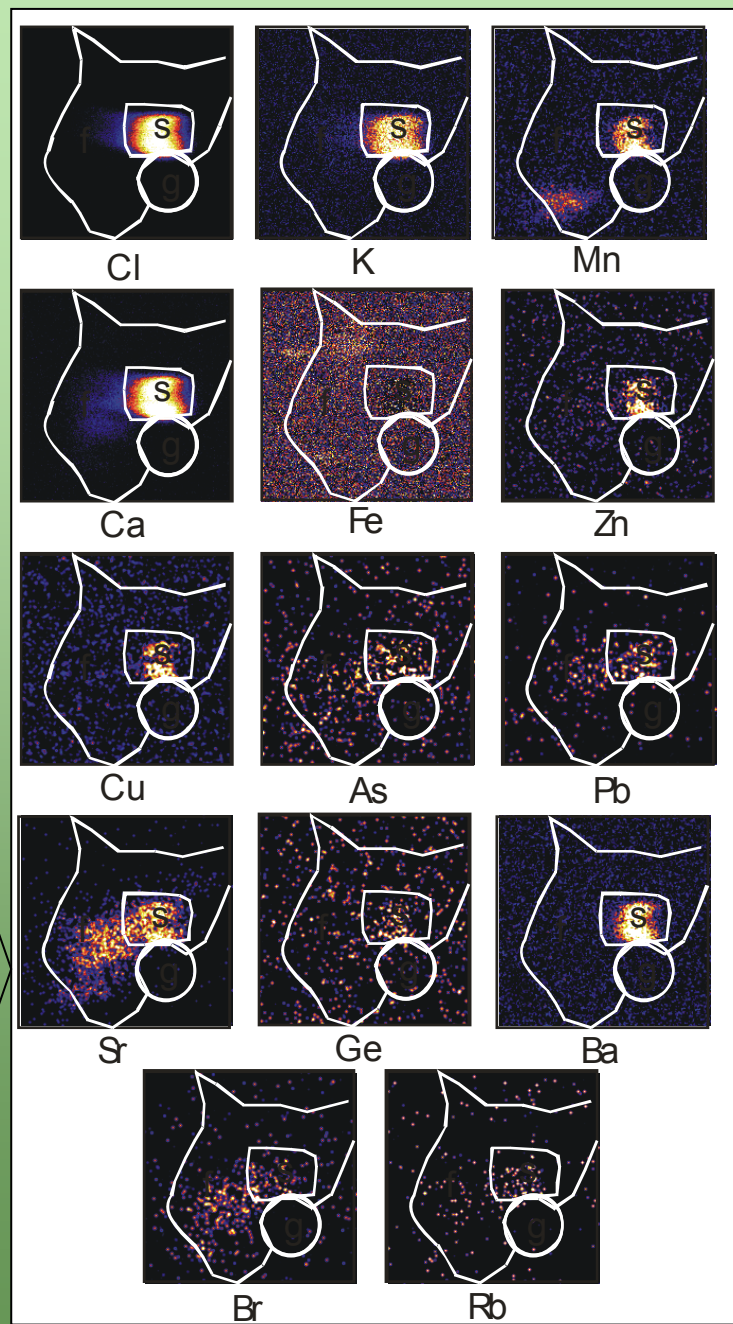
Quartz

LD7113A/135.5m

Th_{total} on quartz of the **Late Cycle**

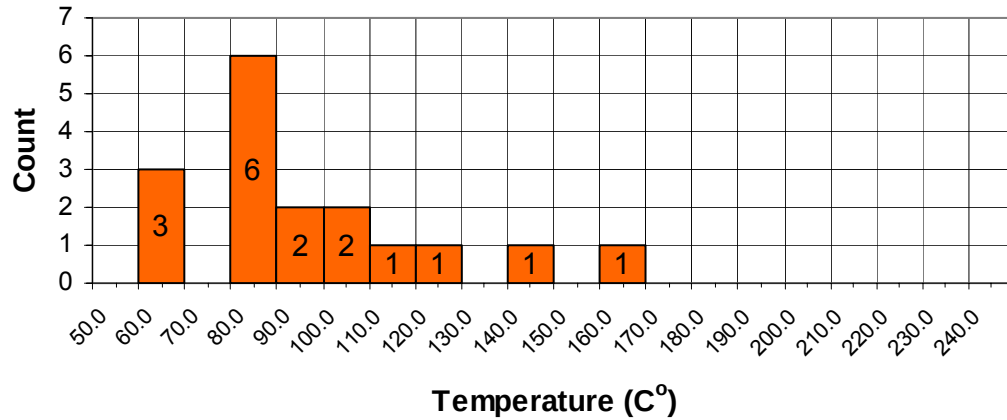


PIXE analysis in quartz 1 of the **Late Cycle**



LD7113A/135.5m

Th_{total} on quartz of the **Late Cycle**

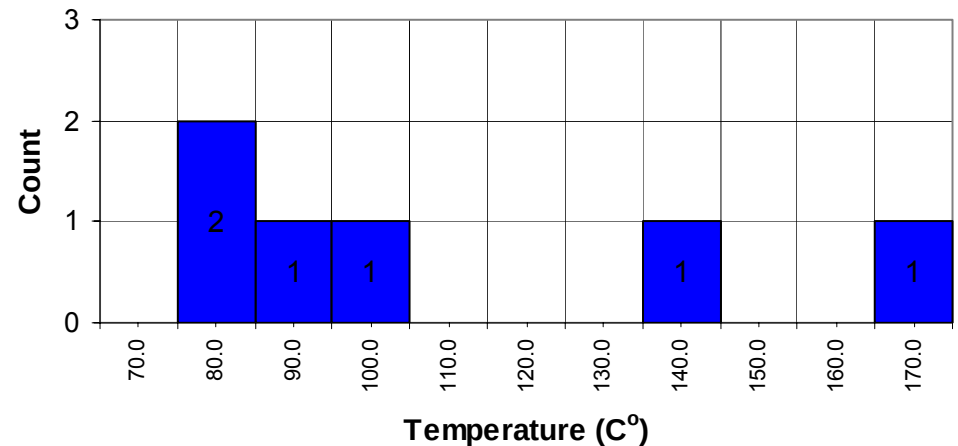


Late Fluid Cycle

Quartz±carbonate

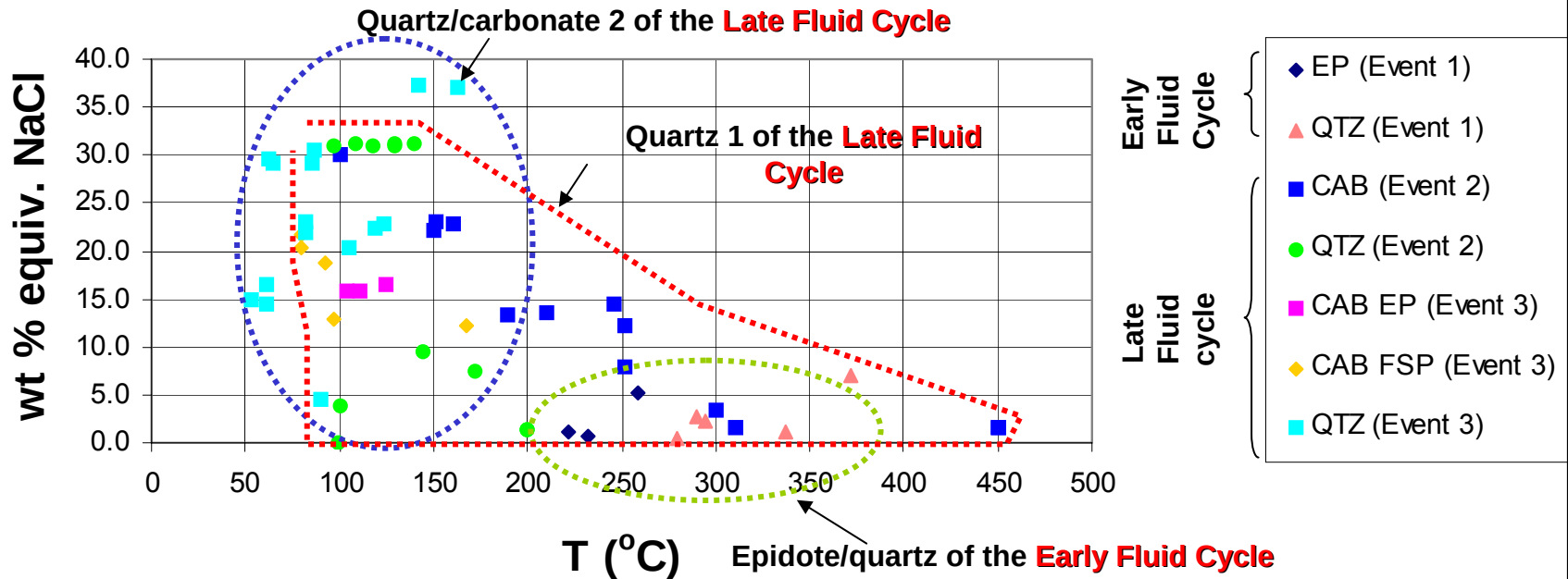
LD7113A/42.8m

Th_{total} on carbonate of the **Late Cycle**



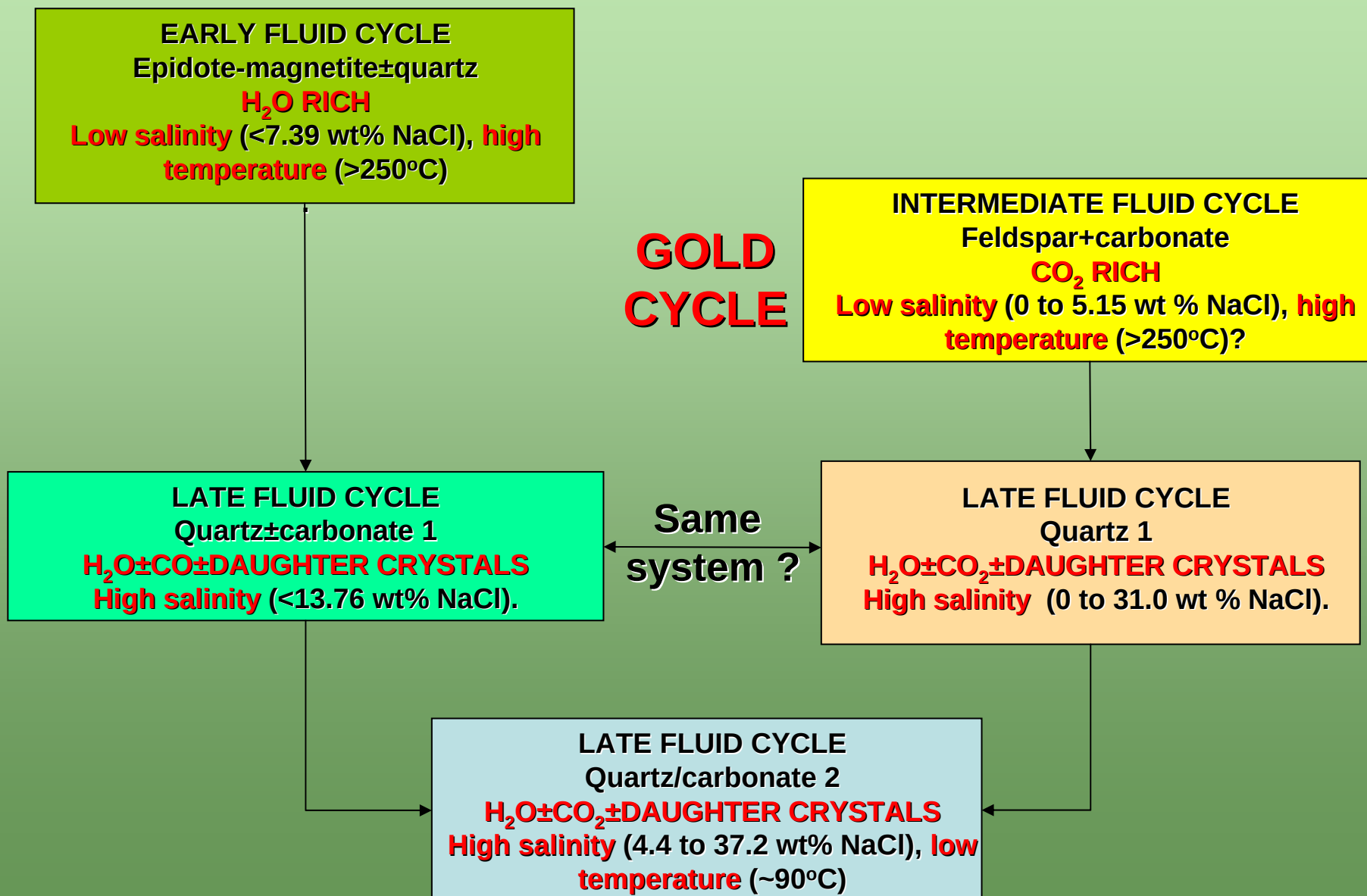
Preliminary fluid evolution model

NaCl X Total homogenization temperature



CO₂ dominant fluids in feldspar and carbonate of the **Intermediate Fluid Cycle (Au)** show salinities between 0 and 5.1 wt % equiv. NaCl.

Fluid evolution in both alteration systems



Preliminary Conclusions

- **Intermediate** fluid cycle plays a major role in the mineralization process and are driven by **highly carbonic fluids**, **low salinity** and **high temperature**.
- Late fluid cycle is out of equilibrium with at least the intermediate fluid cycle and show **highly aqueous**, **high salinity** and **lower temperatures**
- Daughter crystals in Late fluid cycle contain Cl, K, Mn, Ca, Zn, Cu and Ba.

New Celebration Lode-gold Deposits: Multiple Deformation Events and Two Stages of Gold Mineralization

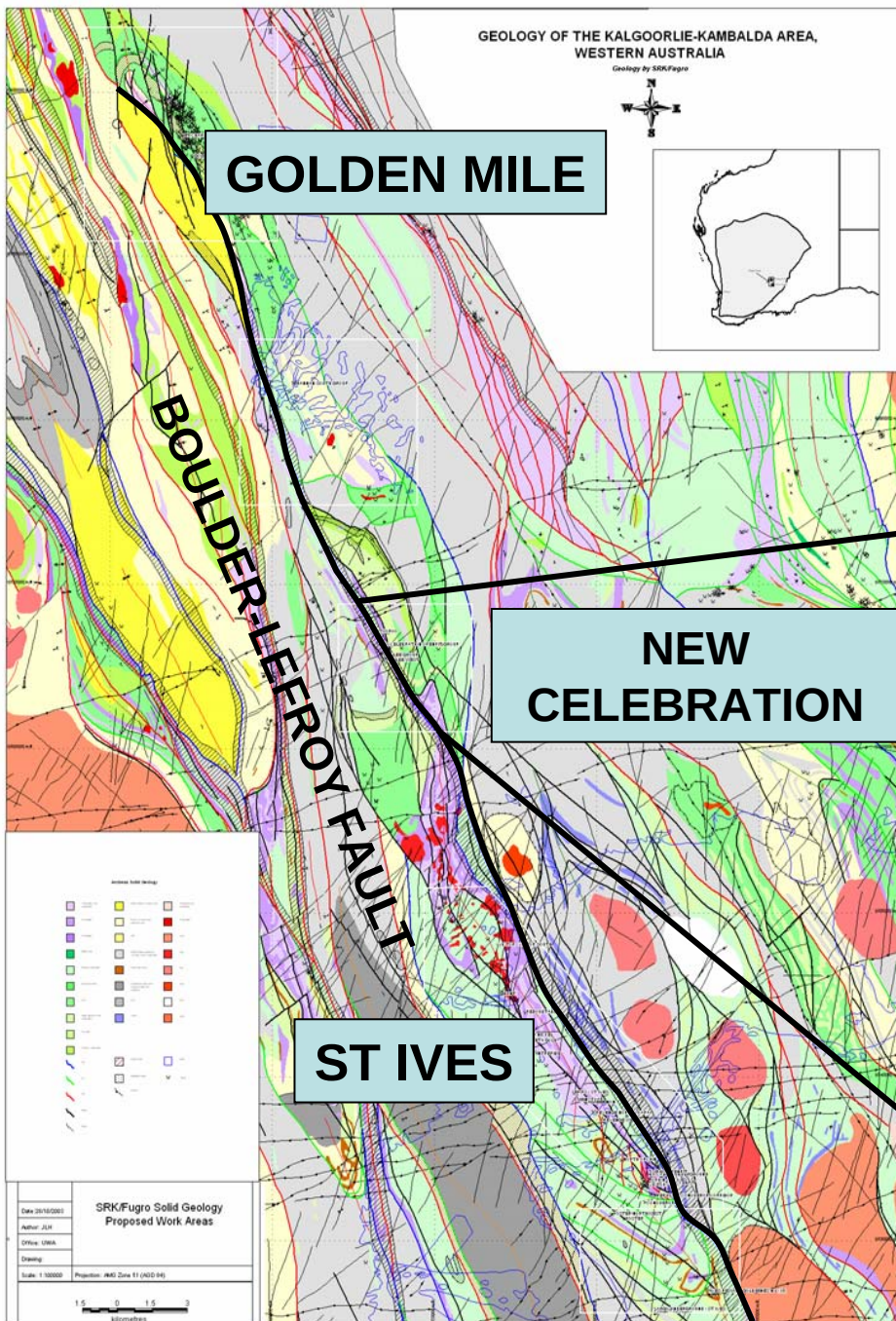
Joanna Hodge, Sian Nichols, Steffen Hagemann and Peter Neumayr

Objectives

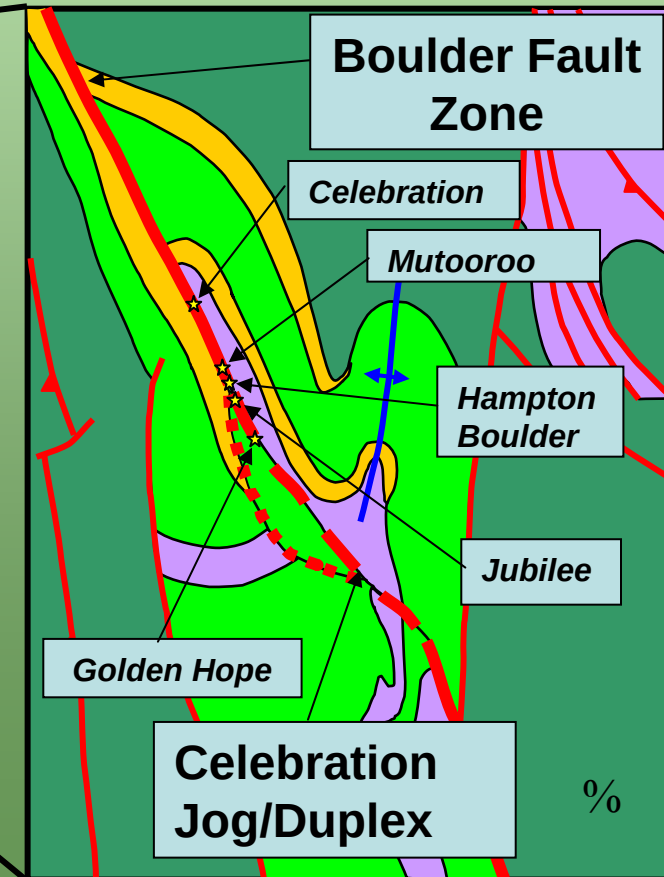
- Key location to understand P-T-X- fO_2 -t conditions of mineralizing and non-mineralizing fault-zone fluids
- Hosted within Boulder-Lefroy Fault Zone, which is spatially correlated to world-class ore deposits
- This study part of thesis research which aims to:
 - Establish time-space correlation between deformation and fault-zone fluids in Kalgoorlie-Kambalda region
 - Improve understanding of role major structures play in mineralization

Outline

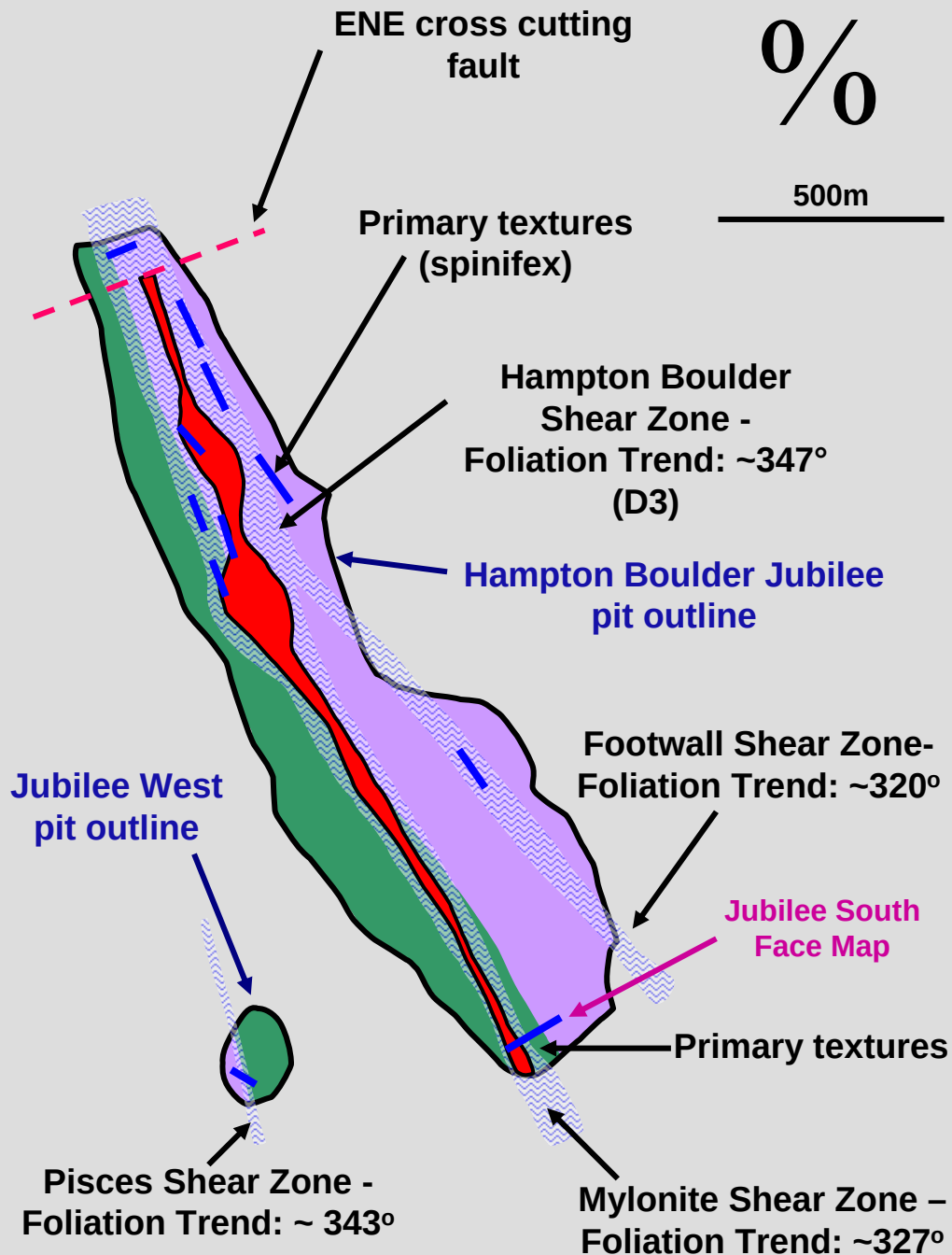
- Regional Setting
- New Celebration Structural Architecture
- Mineralization
- Vein System
- Fluid Inclusions
- Stable Isotopes
- Fluid Summary
- Future Work



- Gold discovered in 1988 
- Mined episodically *pmd***CRC*
- Total modern production (underground & open pit) 19,831,942 tonnes @ 2.40g/t for 1,531,679 oz



Boulder Fault Zone at New Celebration



Legend

- Quartz-Feldspar Porphyry
- Differentiated Dolerite
- Komatiite
- Shear Zone
- Cross Fault
- Mapped Exposure (2003)

Nichols, 2003

New Celebration - Structural Architecture

- Four deformation events recognized
 - D2_{NC} – upright folding
 - D3_{NC} – sinistral oblique-slip movement
 - D4_{NC} – strike-slip movement
 - D4+n_{NC} – brittle faulting, unknown movement
- Tentative correlation with regional deformation events
- Two magmatic events
 - M1 – plagioclase porphyry – S3 foliated
 - M2 – quartz-feldspar porphyry – not foliated

D_{4a}: Poorly developed penetrative foliation

D₂: Sub-vertical stratigraphic contacts

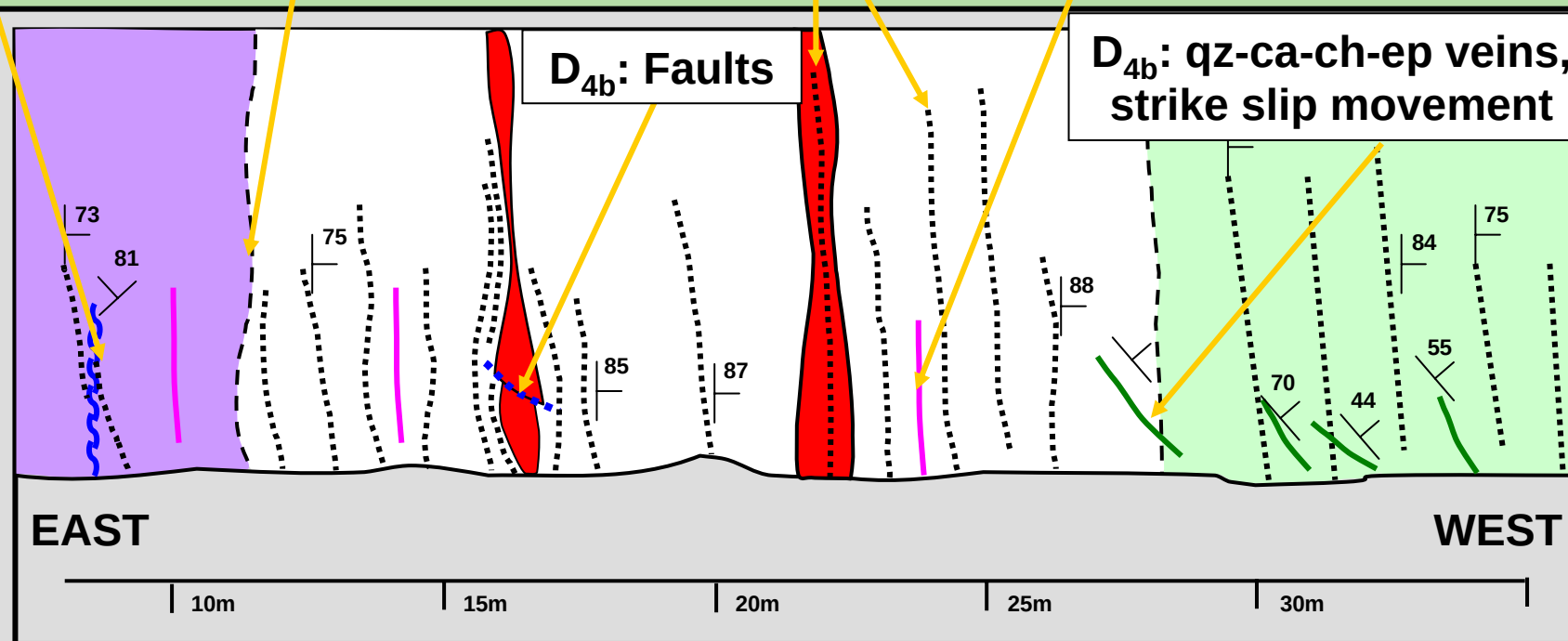
D_{3a}: Sub-vertical penetrative foliation

D_{3b}: Foliation parallel qz-ca veins

*pmd**CRC

D_{4b}: Faults

D_{4b}: qz-ca-ch-ep veins, strike slip movement



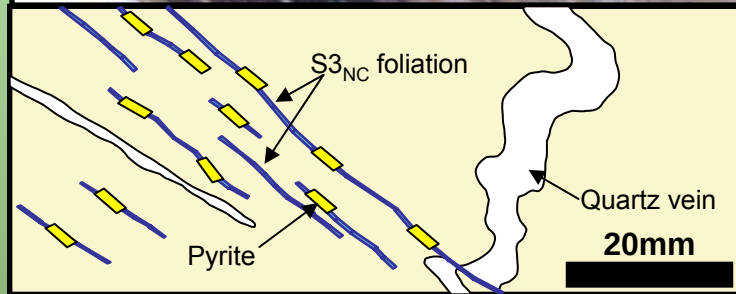
- Porphyry
- Basalt
- High Mg Dolerite
- Ultramafic

- D_{3a} Foliation
- D_{3b} qz-ca vein
- ~~~~~ D_{4a} Foliation
- D_{4b} Faults & Veins

Mineralization

- Two Mineralizing Events & Four Mineralization Styles
 - **Early, ductile (Syn D3_{NC})**
 - Mylonite-style
 - Porphyry-style
 - **Late, brittle (Syn D4_{NC})**
 - Contact-style
 - Fracture-style

Early Mineralization

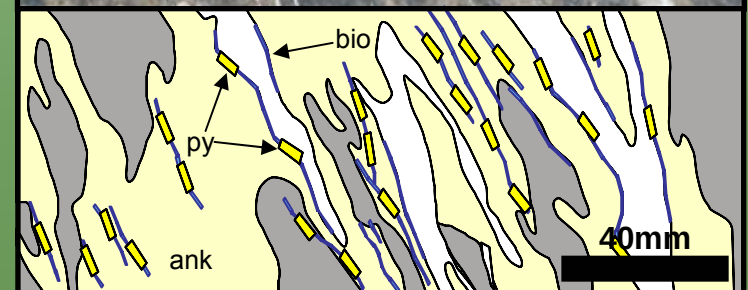


Mylonite-style

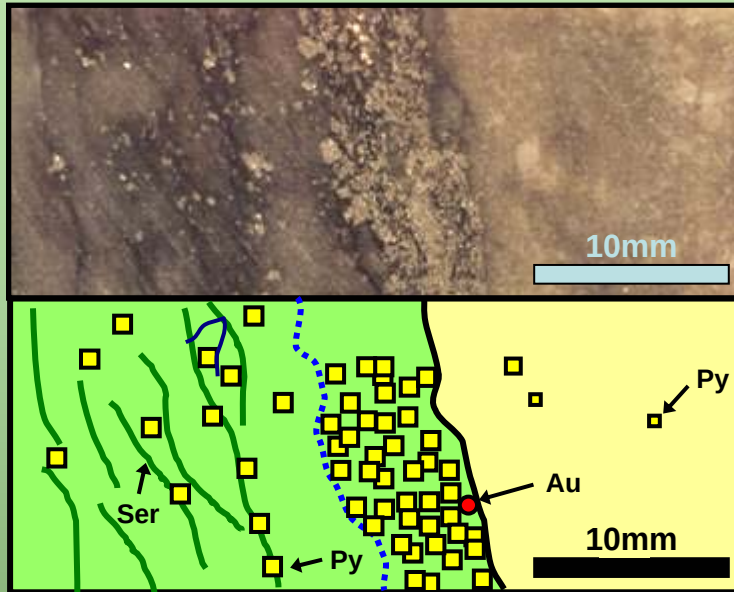
- Au hosted in “dirty” zoned pyrite along foliation planes in qtz-ank-bio-ser mylonite
- Telluride association
- Ank-bio-±py±ser±mt alteration characteristic

Porphyry-style

- Au hosted in pyrite in foliated M1 plagioclase porphyries
- Accessory sulfides, oxides, phosphates and tellurides
- Pyrite aligned parallel to S₃_{NC} foliation planes



Late Mineralization

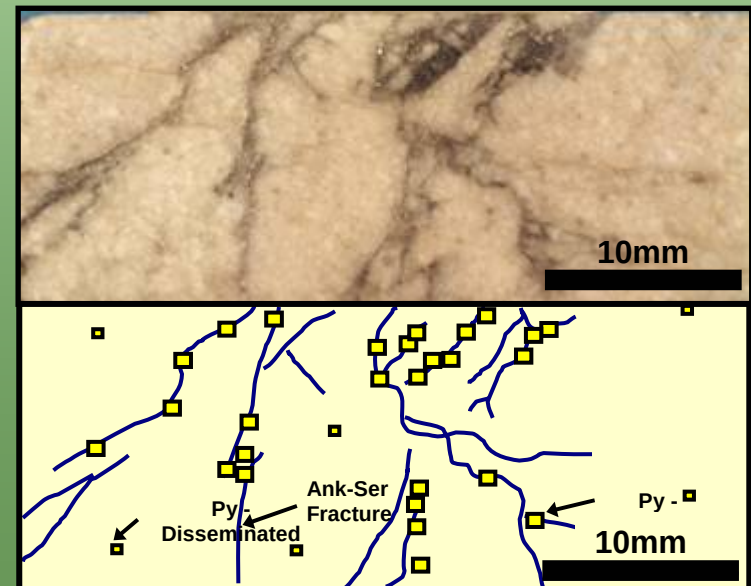


Contact-style

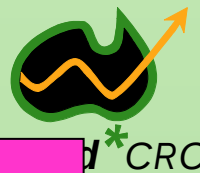
- Au hosted in pyrite at high Mg basalt-M2 porphyry contact
- Well developed alteration halo comprising ank-ser-py±bio±chl

Fracture-style

- Au hosted in pyrite-filled fractures developed along margins of M2 porphyries
- Ank-ser-py alteration characteristic



Structural Location



**Mylonite
Style**

**Fracture
Style**

**Contact
Style**

M₂ Quartz-Feldspar
Porphyry dykes

**Porphyry
Style**

M₁ Plagioclase-
rich Porphyry
dykes

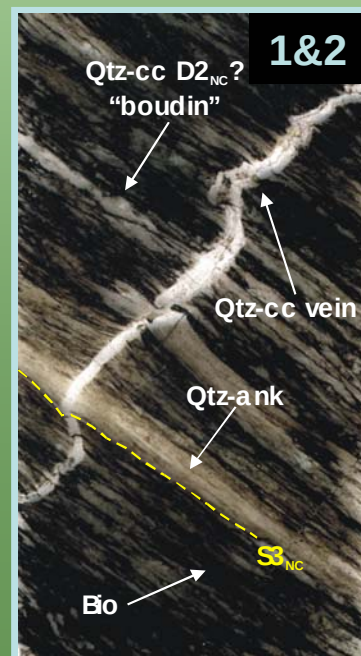
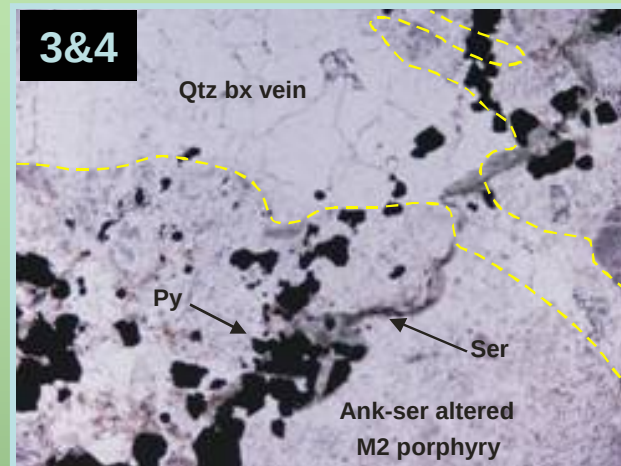
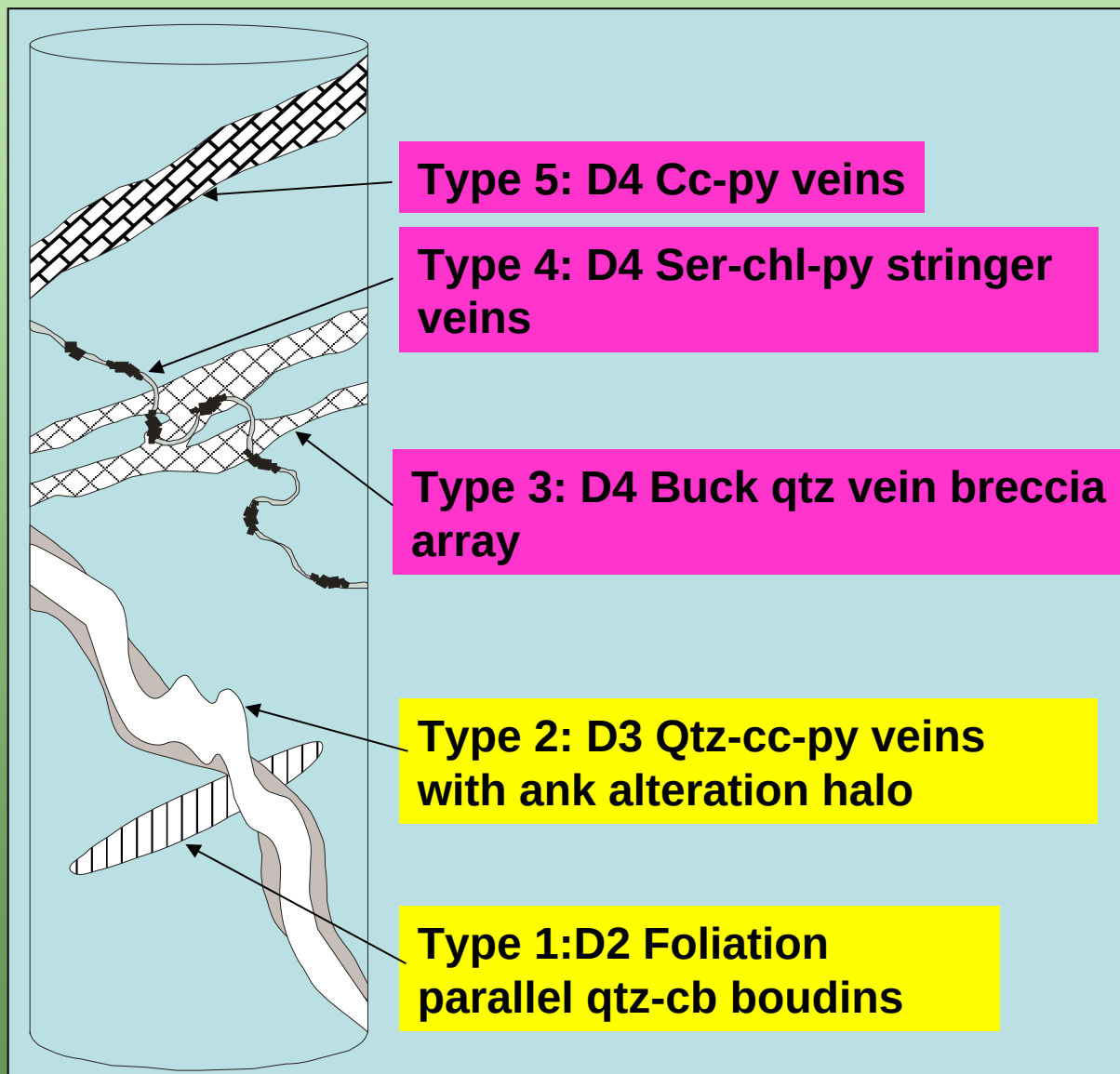
North-northwest
trending, steeply west-
southwest dipping
S_{3NC} foliation

Mafic
hangingwall
rocks

North-northeast
trending, west-northwest
dipping S_{4NC} foliation

Ultramafic
footwall rocks

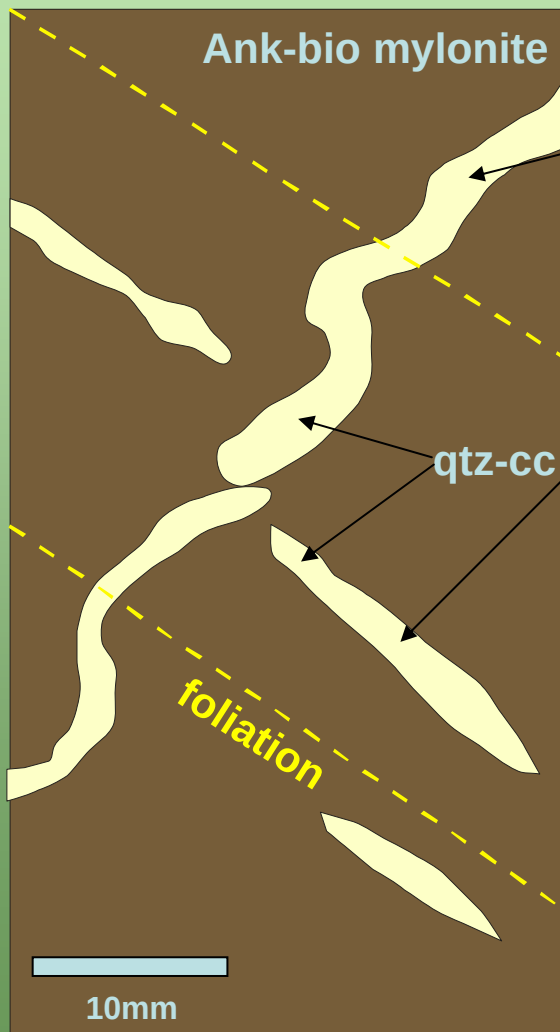
Vein Types



Fluid Inclusions

- Petrography reveals four main inclusion types
 1. CO₂-rich inclusions, mono- or two-phase
 2. H₂O-CO₂ inclusions, two- or three- phase
 - a. Undersaturated with respect to NaCl
 - b. Saturated with respect to NaCl, sulfide, oxide, ± unknown daughter crystals
 3. H₂O inclusions, two- or three-phase
 - a. Undersaturated with respect to NaCl
 - b. Saturated with respect to NaCl
 4. CH₄ (±N₂) inclusions

Early Mineralization – Mylonite



Assemblage 1

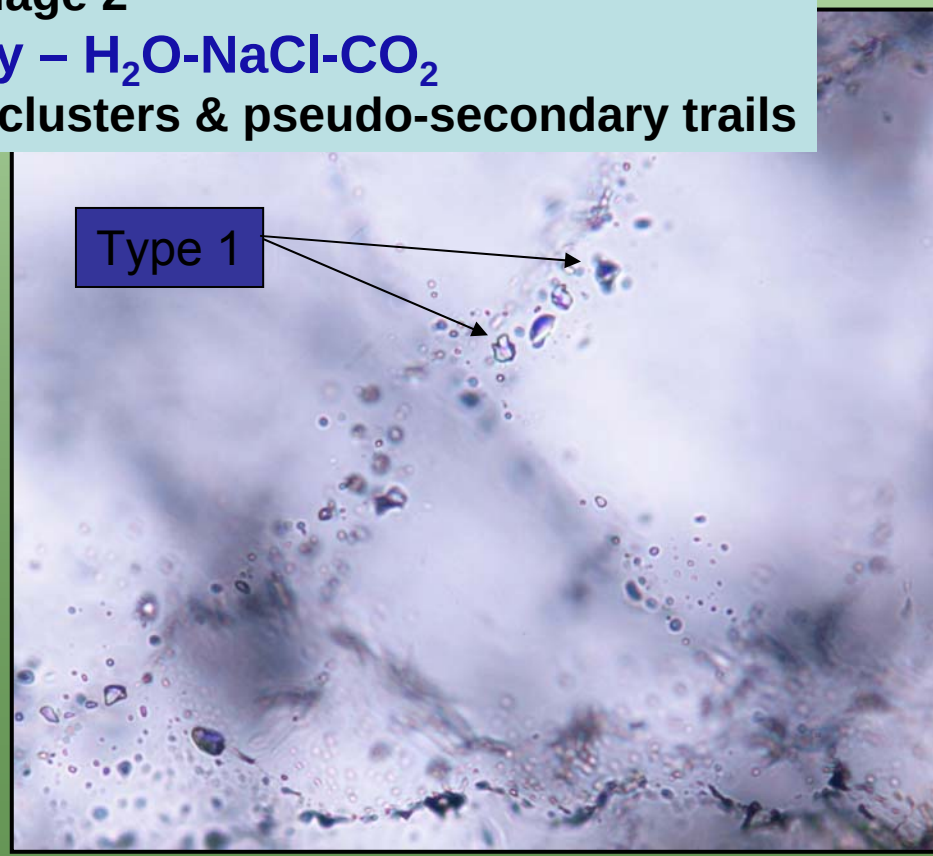
CO₂ only – H₂O-NaCl-CO₂ – H₂O-NaCl

Primary clusters & pseudo-secondary trails

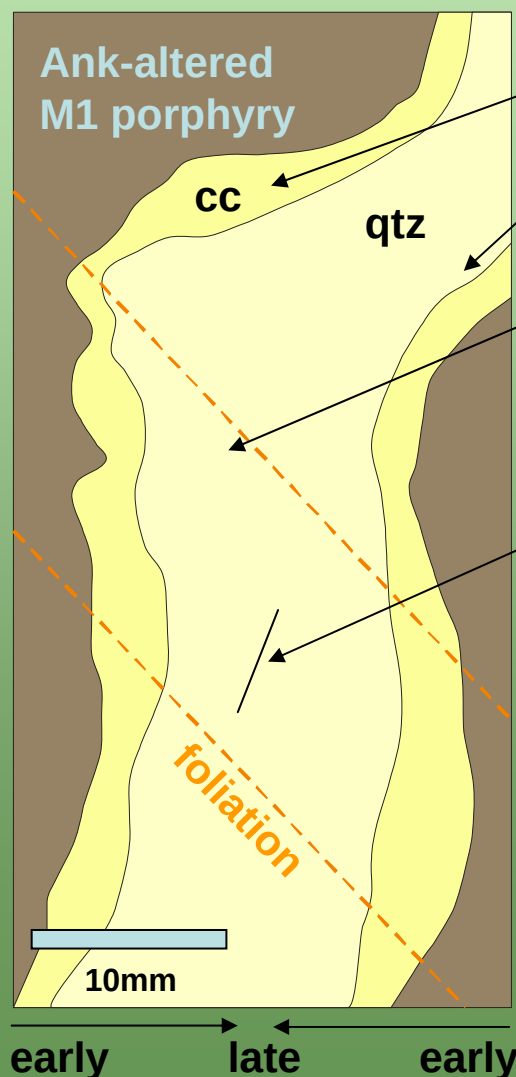
Assemblage 2

CO₂ only – H₂O-NaCl-CO₂

Primary clusters & pseudo-secondary trails



Early Mineralization - Porphyry



Assemblage 1

$\text{H}_2\text{O}-\text{NaCl}-\text{CO}_2 - \text{CH}_4 (\pm \text{N}_2)$

Primary inclusion clusters

Assemblage 2

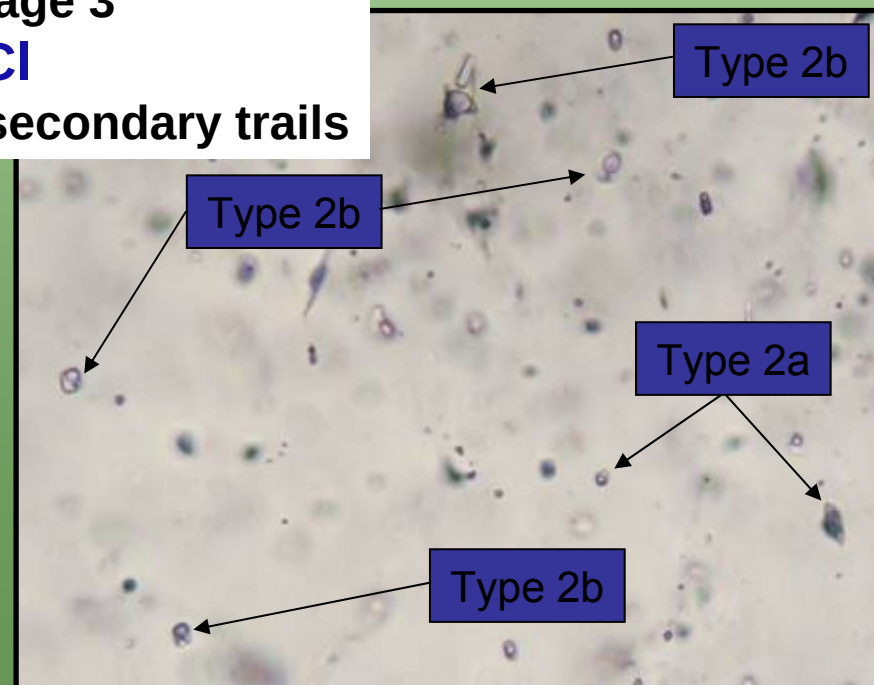
CO_2 only – $\text{H}_2\text{O}-\text{CO}_2 \pm$ daughter minerals

Primary inclusion clusters

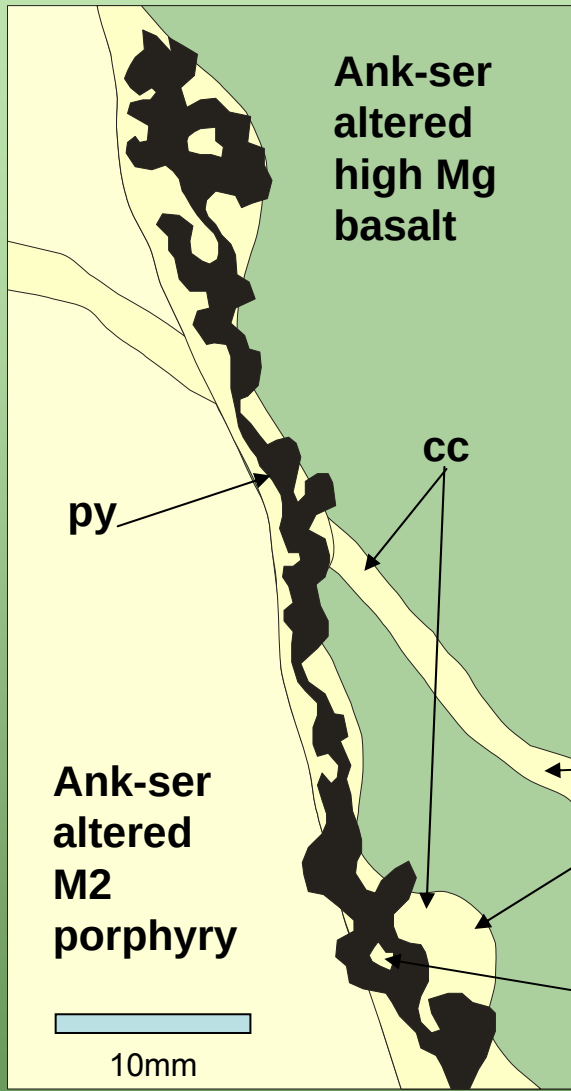
Assemblage 3

$\text{H}_2\text{O}-\text{NaCl}$

Pseudo-secondary trails



Late Mineralization - Contact



Assemblage 1

$H_2O-NaCl-CO_2$

Primary clusters & pseudo-secondary trails

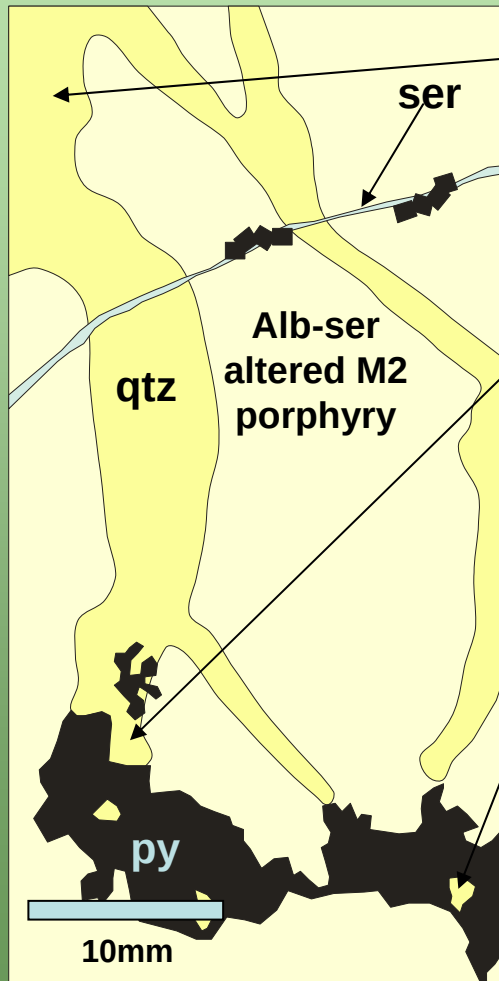
Assemblage 2

$H_2O-NaCl-CO_2$

Primary clusters

Late Mineralization - Fracture

INCREASING SALINITY, DECREASING CO₂



Assemblage 1

H₂O-NaCl-CO₂ – H₂O-NaCl

Pseudo-secondary trails

Assemblage 2

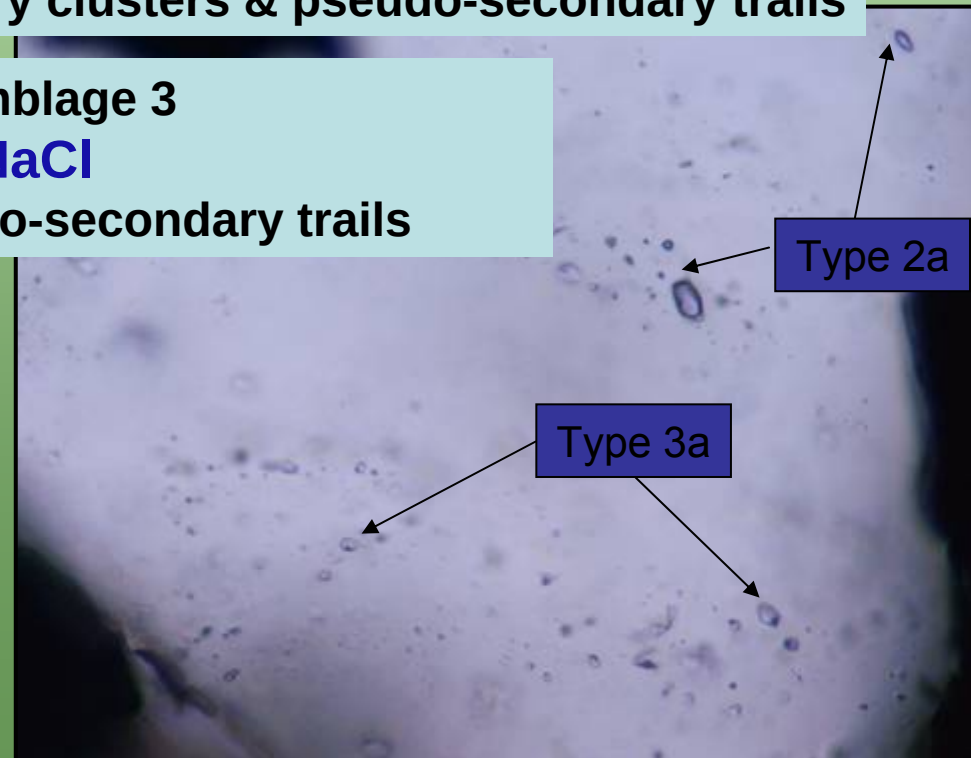
H₂O-NaCl-CO₂ – H₂O-NaCl

Primary clusters & pseudo-secondary trails

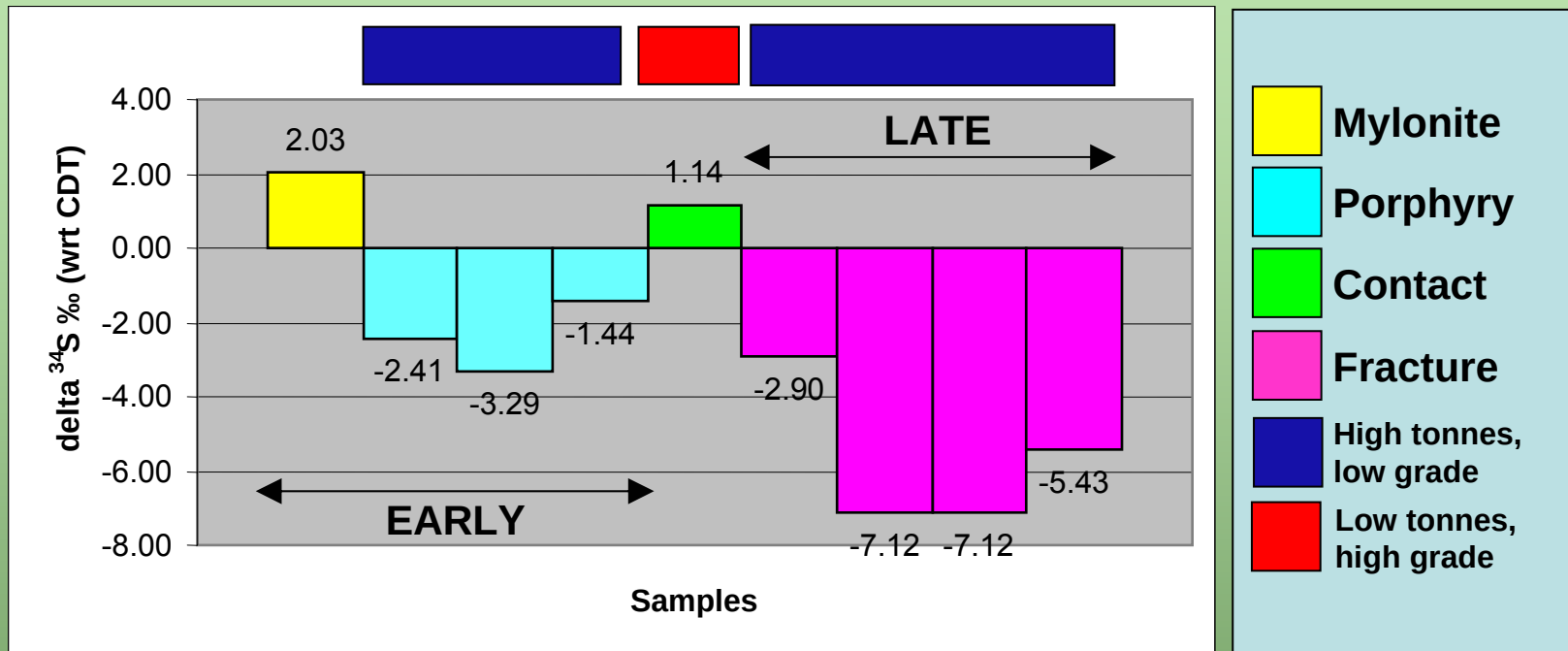
Assemblage 3

H₂O-NaCl

Pseudo-secondary trails



Sulfur Isotopes



- No significant overlap between mineralization styles
- Depleted wrt lode gold deposits world-wide.

Summary

- Four major deformation events
- Two mineralizing events, four mineralization styles
- Progression from early CO_2 $\rightarrow$ late H_2O - NaCl in both mineralizing events
- CH_4 in early mineralizing event
- $\delta^{34}\text{S}$ differentiates mineralization styles

Implications

- Several evolving fluids occurring at different times
- How are they related?
- Are they related?
- 4D evolution key to better understanding
- Time-space relationships critical
- Absolute timing constraints vital



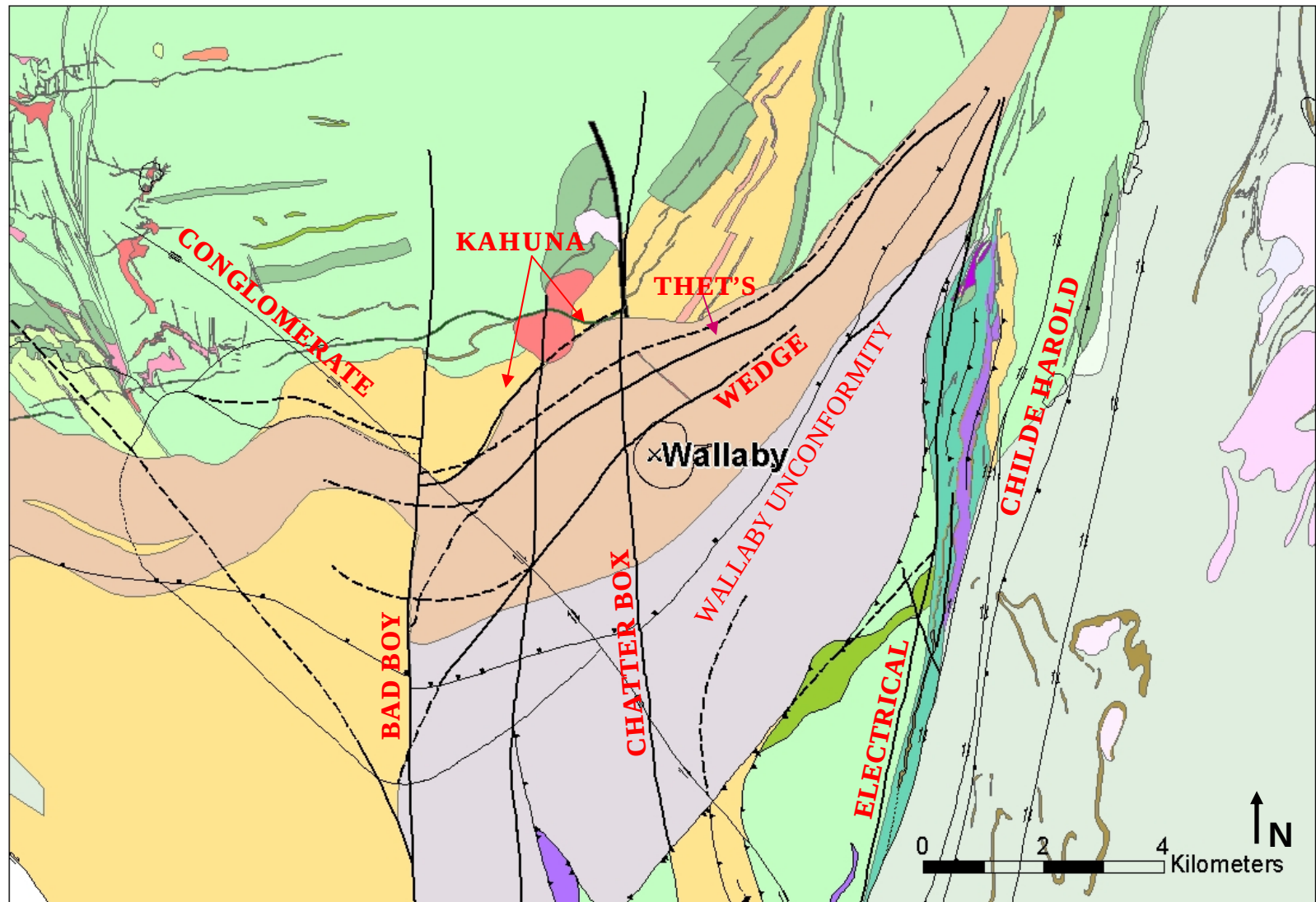
Embedded Insights into the Wallaby Gold Deposit, Western Australia

Susan Drieberg

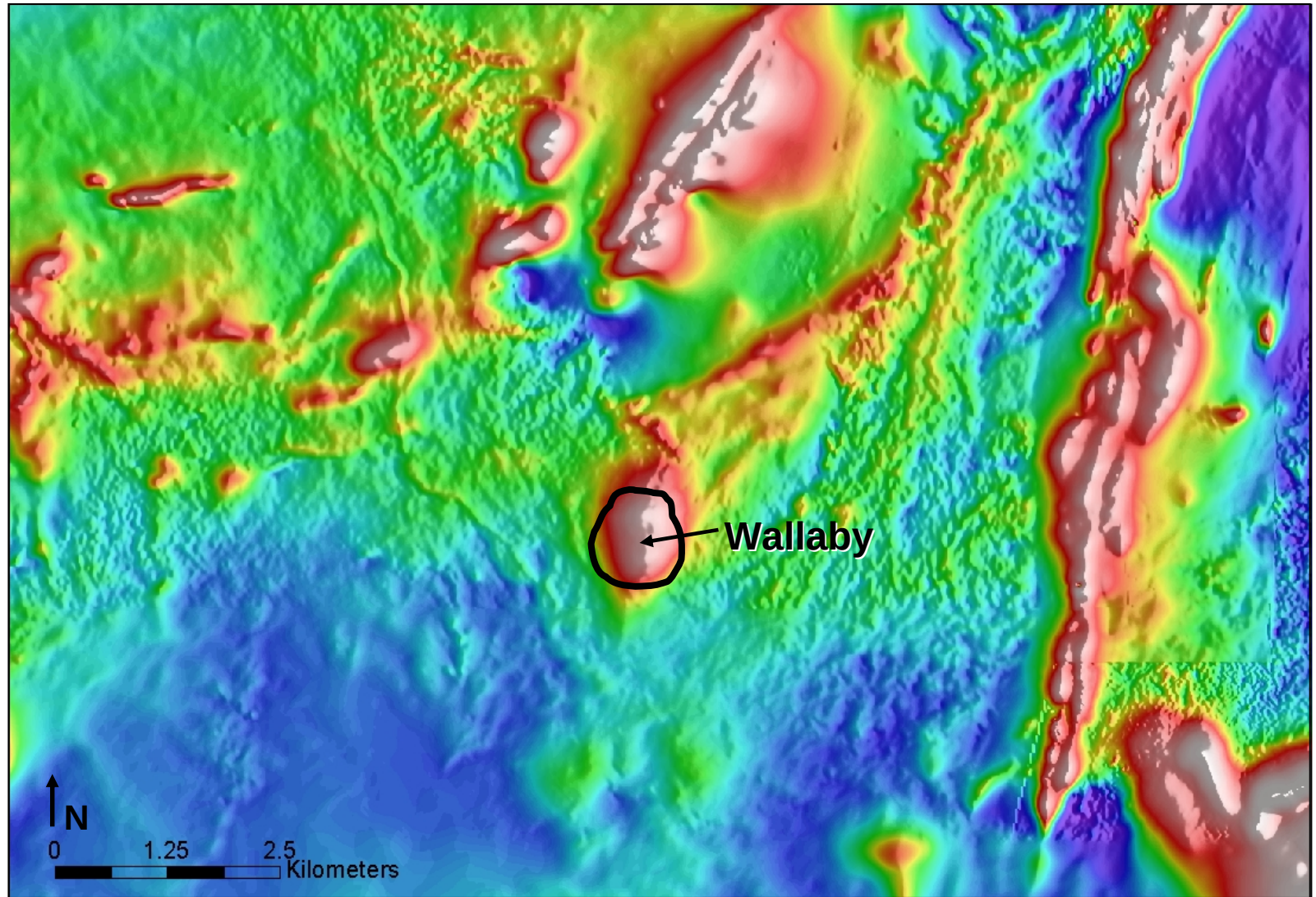
Placer Dome Asia Pacific
Granny Smith Minesite
and
University of Western Australia

Wallaby Regional Geology

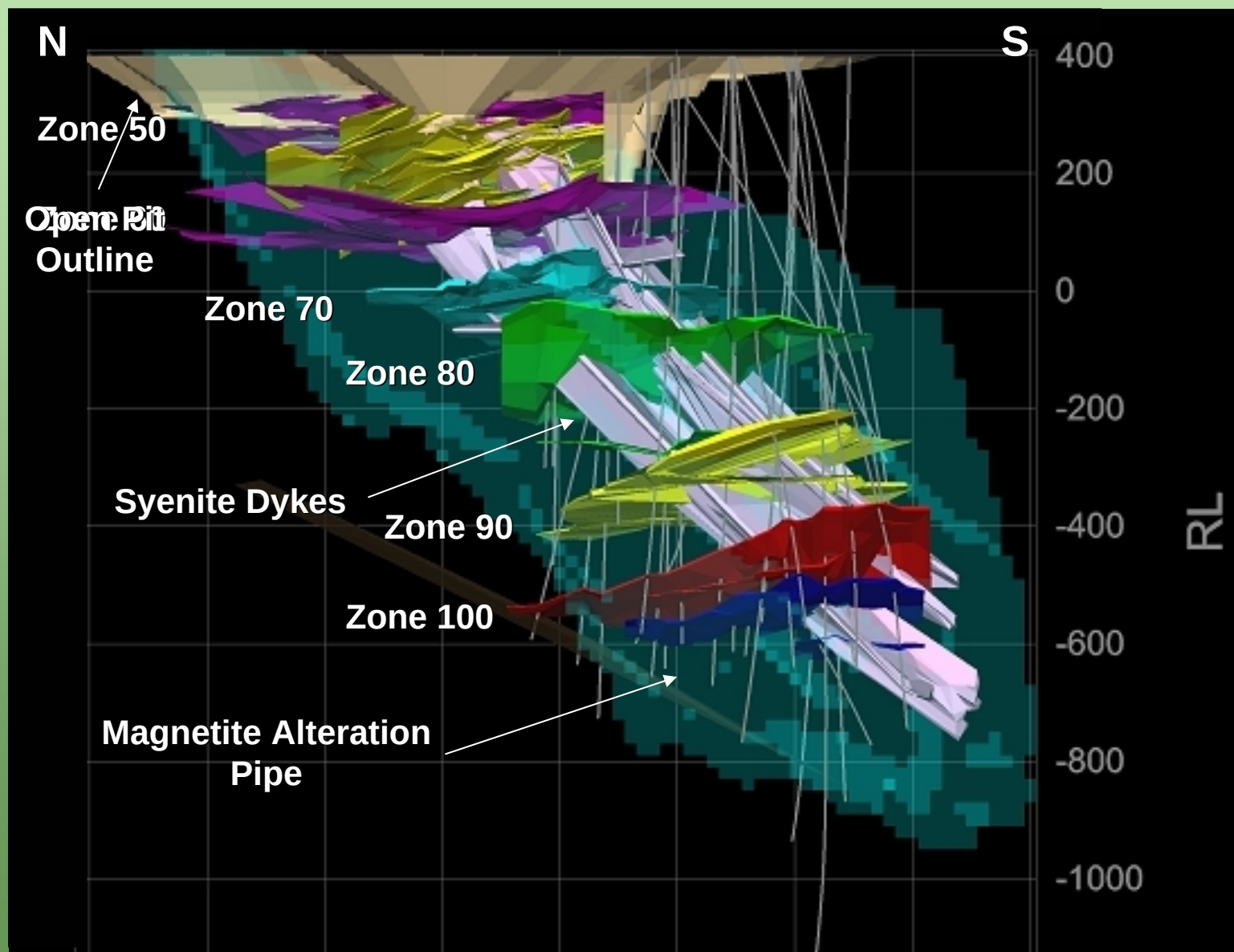
Rega Corridor, Laverton Tectonic Zone



Wallaby Magnetic Signature



Wallaby Mineralization



Wallaby Conglomerate



- Polymict, matrix-supported conglomerate
- Well-rounded pebble to cobble sized clasts
- >1500m thick
- Typically unbedded; no distinct marker horizons
- Right-way-up; dipping 45° to SE

Intrusive Phases

Biotite Monzonite



Monzonite



Syenite



Syenite Porphyry



Intrusive Phases - continued

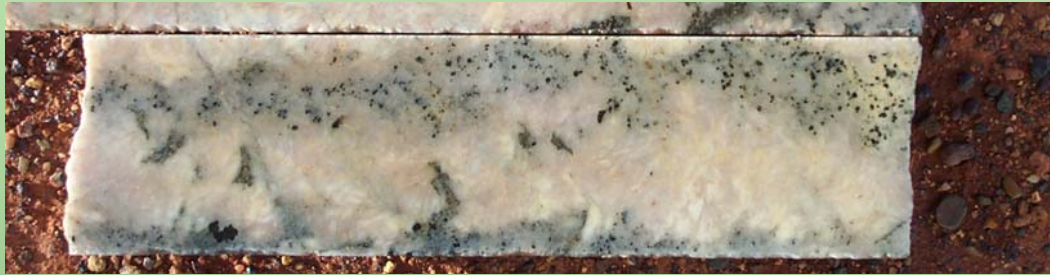
Lamprophyre



Carbonatite



Carbonate $\pm$ Biotite $\pm$ Magnetite $\pm$ Pyrite Veins



Ore-Related Quartz-Carbonate Breccias

250 ore zone



Pre-Mineralization Alteration of the Conglomerate



Chlorite-Calcite

- Distal alteration
- $\pm$ Magnetite
- Regional metamorphism



Actinolite-Magnetite

- Proximal alteration
- “Wallaby Pipe”
- Strongly magnetic

High Grade Alteration

- Intense bleaching = Dolomite-albite-pyrite (ASRC) alteration
- Main flat-lying ore zones typically have one sharp boundary



Low Grade Alteration

- Dolomite-albite-hematite±pyrite (ASRH) alteration.



High-grade ASRC alteration grading into low-grade ASRH alteration is characteristic of the base of main flat-lying ore zones.



22.11.2002

Preliminary Results

PROJECT	OUTCOMES
Structural Controls on Grade Distribution	• Highest gold grade occurs at inflection points in a ramp-flat geometry • Allows better constraints for open pit mining methods • Provides confidence in the models used to develop underground mining operations
Chemical Controls on Grade Distribution	• Genetic model—fluid mixing scenarios versus sulfidation reactions • Feeds back into mining methods • Feeds back into the exploration model
Ore and Intrusive Relationships	• Better constraints on geochronology samples • Genetic model for the formation of Wallaby • Exploration model → Which, if any, intrusive phases are important?

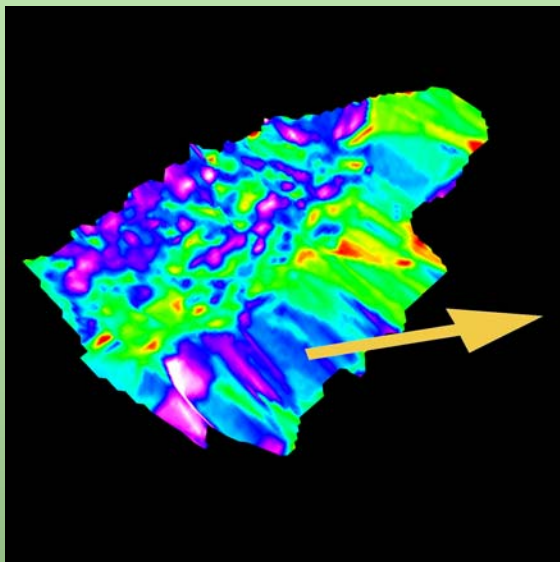
Modelling Grade Distribution in the 240 Ore Zone

- 1. Combined exploration drill holes, grade control holes, blast hole samples, and pit mapping**
- 2. Examined both gold grade and alteration distribution**
- 3. Sectional interpretations to constrain the boundaries of 240**
- 4. Triangulation to produce a bounding surface for 240**
- 5. Block modelled for average grade, grade times thickness, and the midpoint plane**
- 6. Connolly analysis of midpoint plane to produce local strike and dip data**

Dip

Red/yellow/
green =
10-20°

Dark
blue/purple =
45-55 °

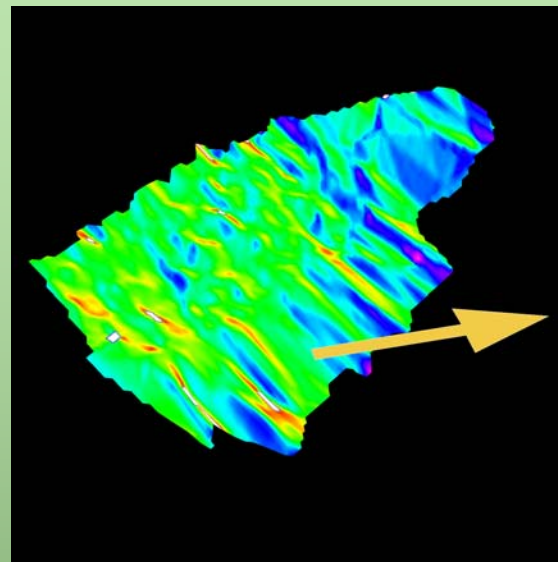


Azimuth

Red = N

Green = NE

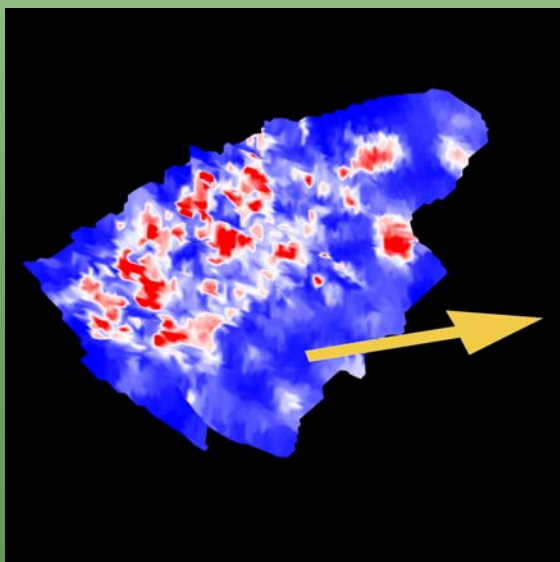
Blue = E, ESE



Average Grade

Blue = 1 g/t

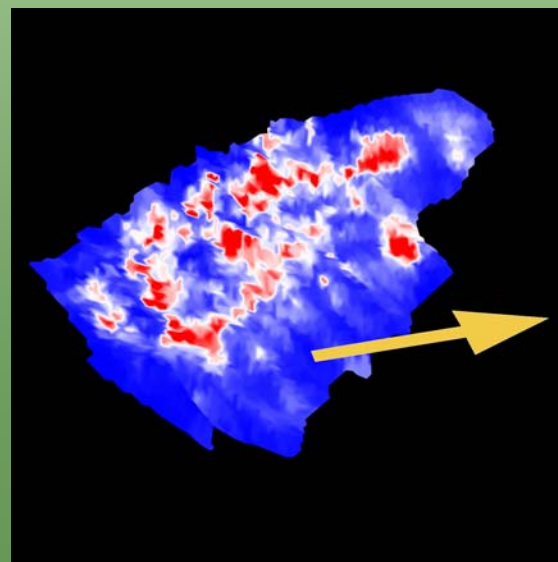
Red = 20 g/t



Grade- Thickness

Blue = 1.4 gm

Red = 202 gm

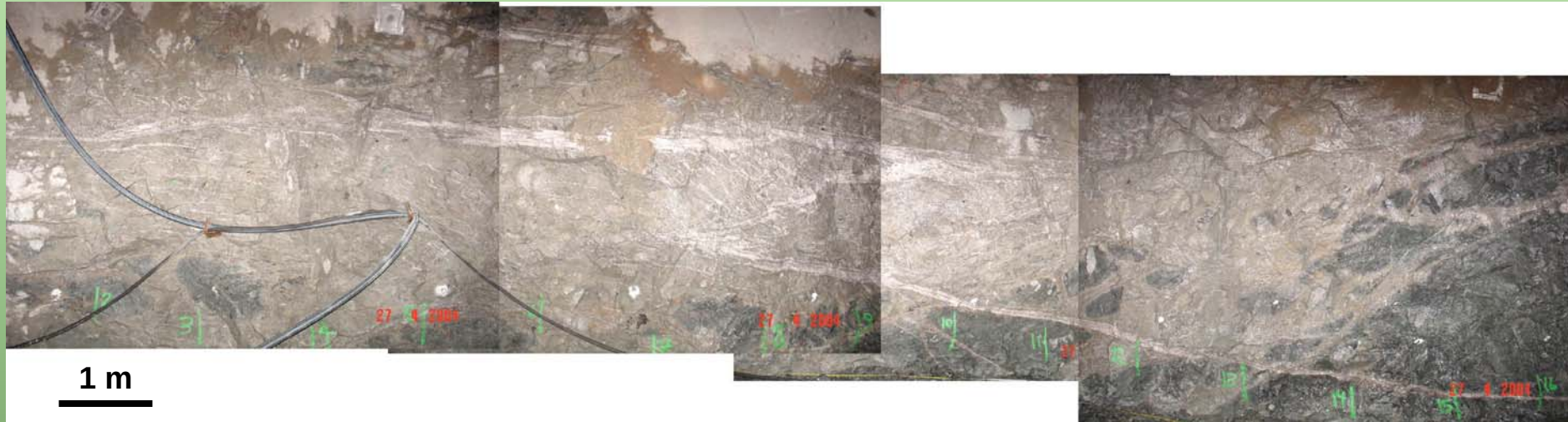


WBUG, 250 Ore Zone, 1215 Drive

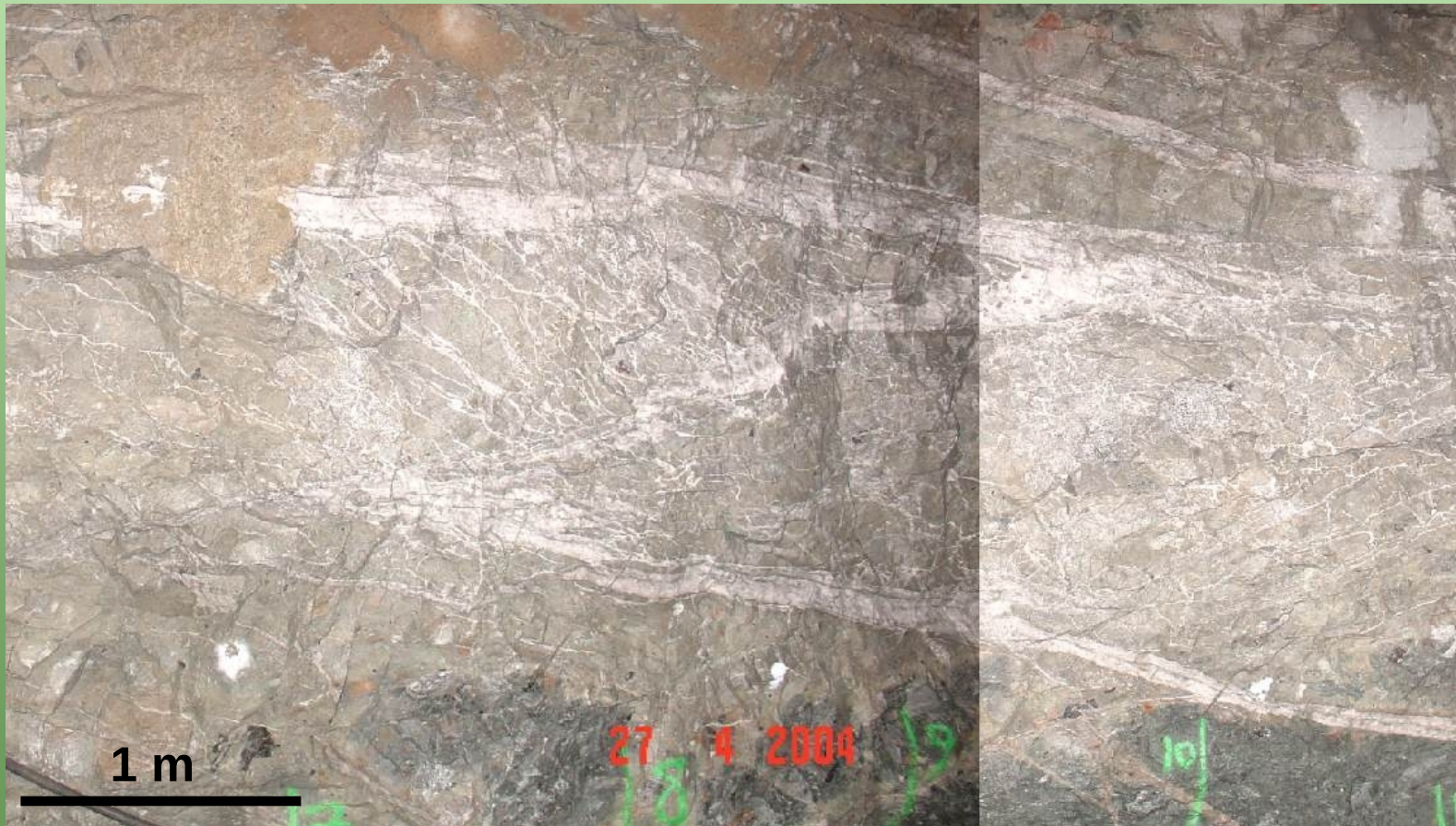


- Bounding structures are laminated quartz-albite veins
- Linking vein is extensional quartz-carbonate vein
- Huge blow-out in both alteration and grade where these elements combine
- Produces high-grade pods within the ore zone

WBUG, 250 Ore Zone, 1217 Drive



WBUG, 250 Ore Zone, 1217 Drive



Preliminary Results

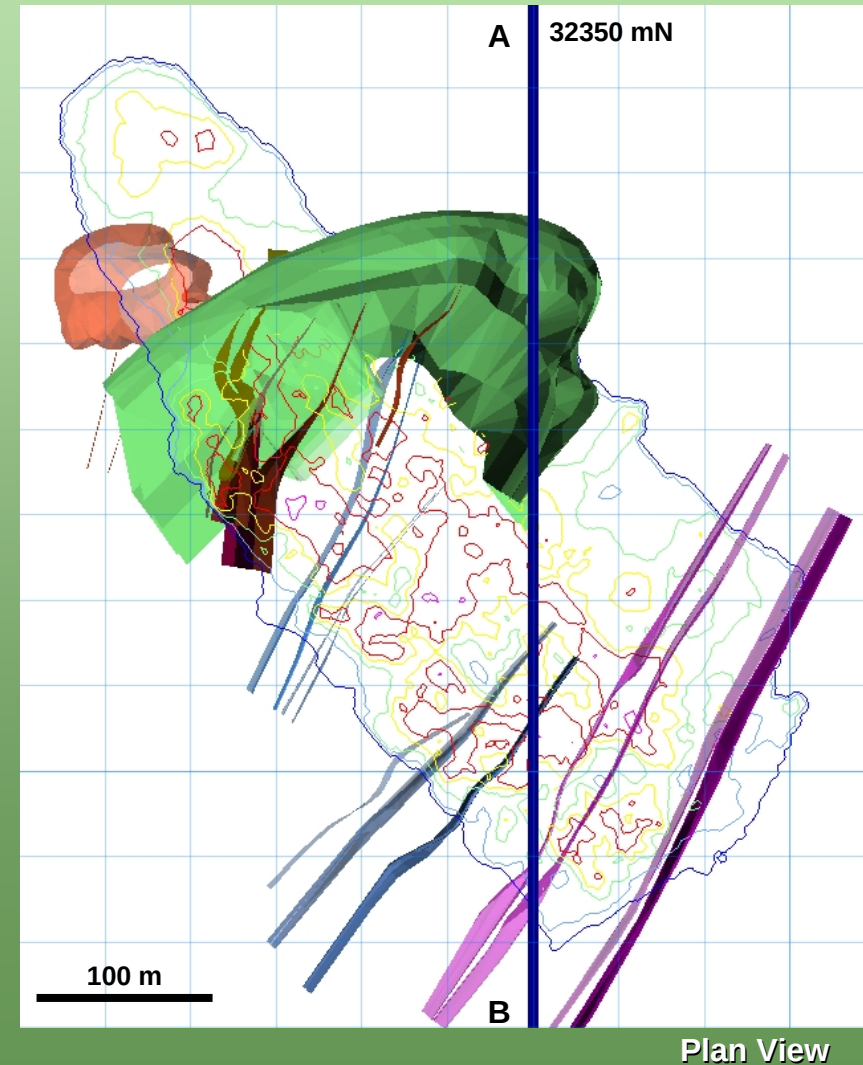
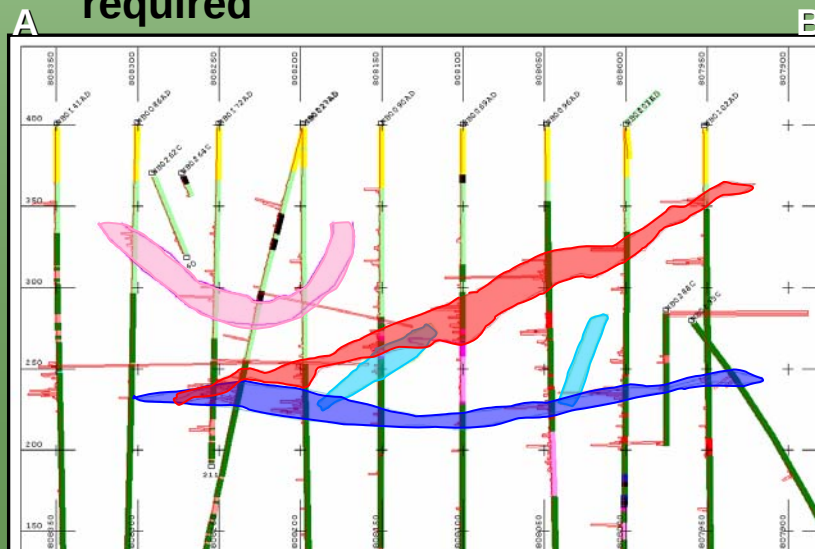
PROJECT	OUTCOMES
Structural Controls on Grade Distribution	• Highest gold grade occurs at inflection points in a ramp-flat geometry • Allows better constraints for open pit mining methods • Provides confidence in the models used to develop underground mining operations
Chemical Controls on Grade Distribution	• Genetic model—fluid mixing scenarios versus sulfidation reactions • Feeds back into mining methods • Feeds back into the exploration model
Ore and Intrusive Relationships	• Better constraints on geochronology samples • Genetic model for the formation of Wallaby • Exploration model → Which, if any, intrusive phases are important?

Preliminary Results

PROJECT	OUTCOMES
Structural Controls on Grade Distribution	• Highest gold grade occurs at inflection points in a ramp-flat geometry • Allows better constraints for open pit mining methods • Provides confidence in the models used to develop underground mining operations
Chemical Controls on Grade Distribution	• Genetic model—fluid mixing scenarios versus sulfidation reactions • Feeds back into mining methods • Feeds back into the exploration model
Ore and Intrusive Relationships	• Better constraints on geochronology samples • Genetic model for the formation of Wallaby • Exploration model → Which, if any, intrusive phases are important?

Chemical Controls on Gold Grade Distribution

- **North-south cross-section through the 240 ore zone**
- **Detailed core logging**
- **PIMA spectral interpretation**
- **Lithogeochemistry**
- **Basis for future fluid inclusion studies, stable isotope analyses, any additional detailed work required**



Zoned Alteration

**Biotite+carbonate
shear**

Pyrite replacing magnetite

Biotite

Carbonate+magnetite

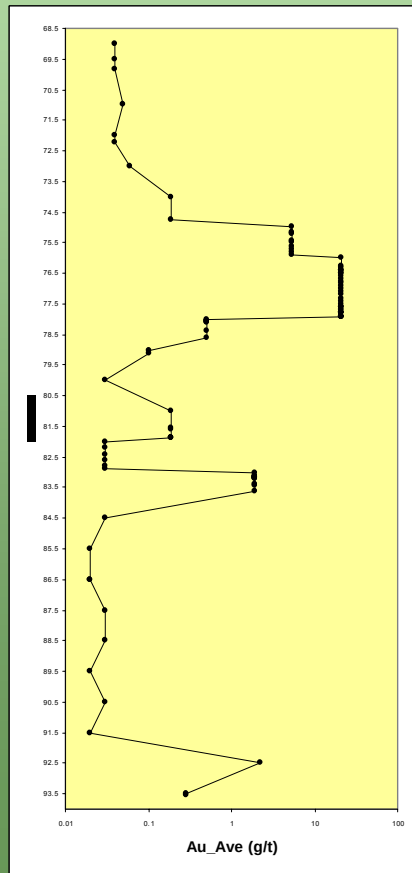
Dolomite-Albite-Pyrite



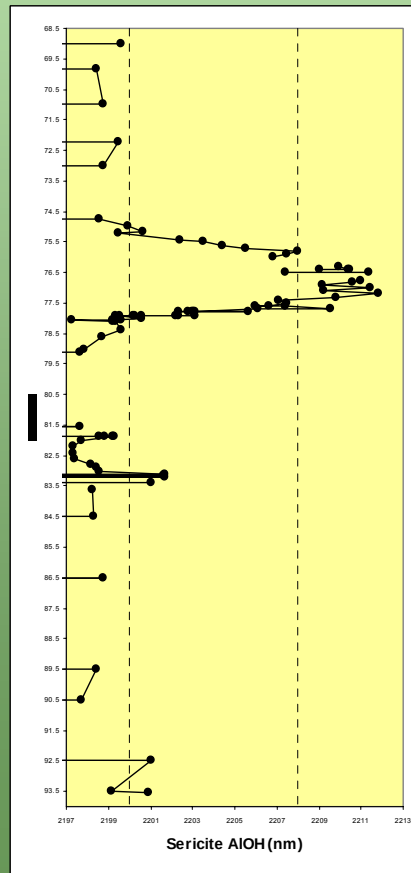
PIMA Spectral Information

WB0101AD, 68 to 94m

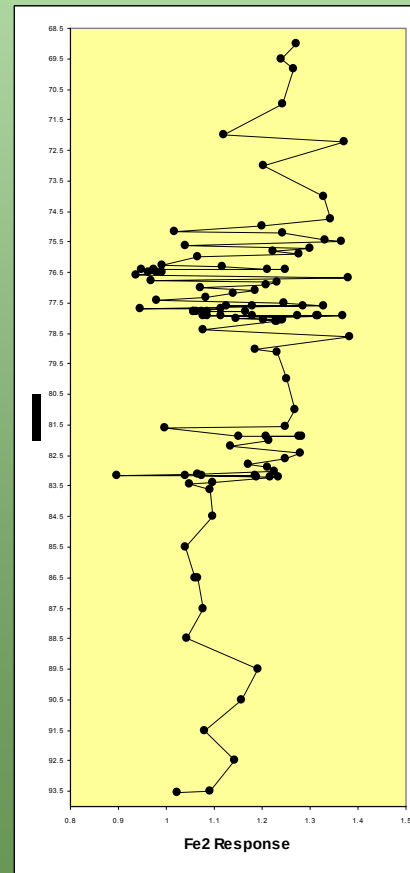
Gold Grade



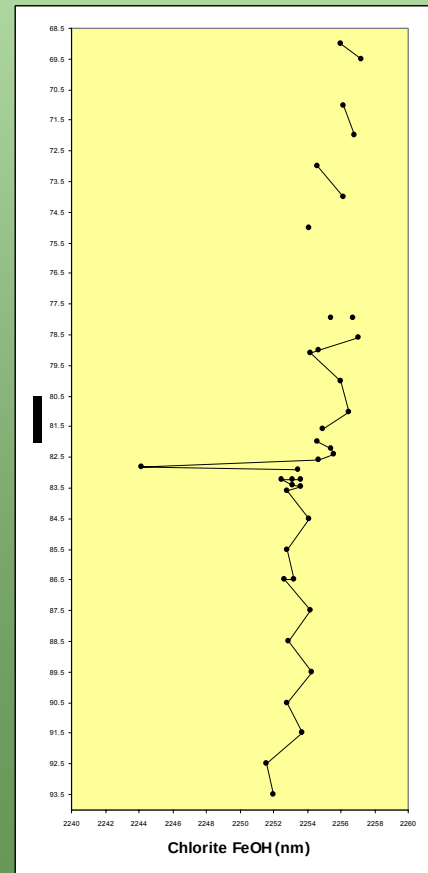
Sericite AIOH



Fe²⁺ Response



Chlorite FeOH



Preliminary Results

PROJECT	OUTCOMES
Structural Controls on Grade Distribution	• Highest gold grade occurs at inflection points in a ramp-flat geometry • Allows better constraints for open pit mining methods • Provides confidence in the models used to develop underground mining operations
Chemical Controls on Grade Distribution	• Genetic model—fluid mixing scenarios versus sulfidation reactions • Feeds back into mining methods • Feeds back into the exploration model
Ore and Intrusive Relationships	• Better constraints on geochronology samples • Genetic model for the formation of Wallaby • Exploration model → Which, if any, intrusive phases are important?

Preliminary Results

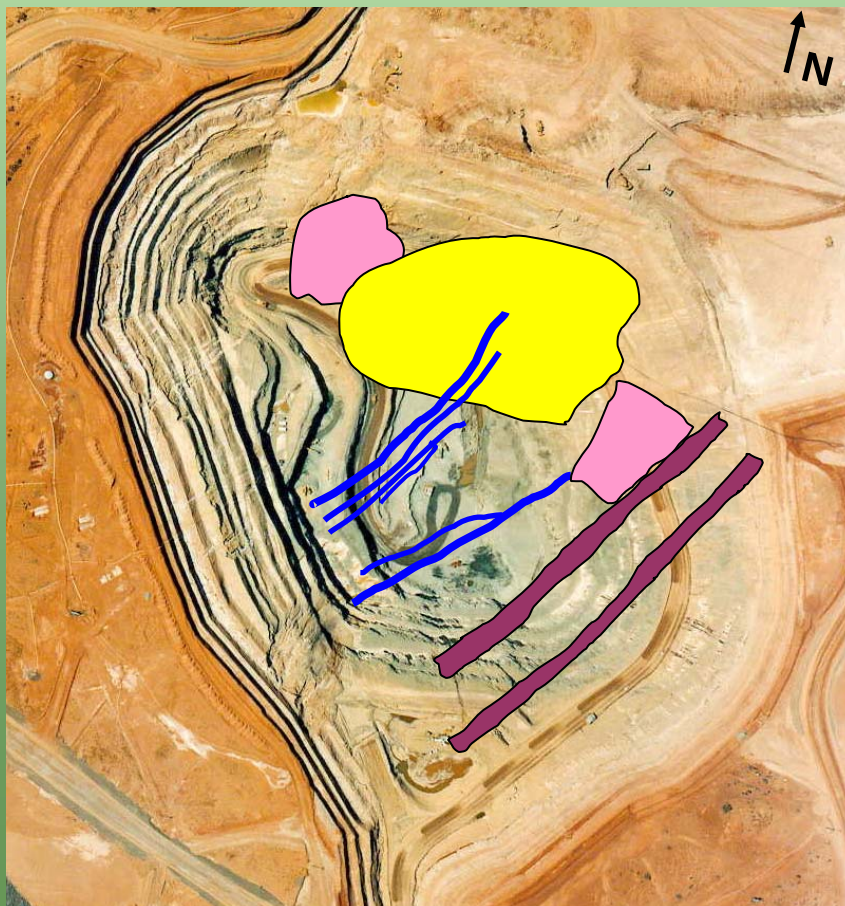
PROJECT	OUTCOMES
Structural Controls on Grade Distribution	• Highest gold grade occurs at inflection points in a ramp-flat geometry • Allows better constraints for open pit mining methods • Provides confidence in the models used to develop underground mining operations
Chemical Controls on Grade Distribution	• Genetic model—fluid mixing scenarios versus sulfidation reactions • Feeds back into mining methods • Feeds back into the exploration model
Ore and Intrusive Relationships	• Better constraints on geochronology samples • Genetic model for the formation of Wallaby • Exploration model → Which, if any, intrusive phases are important?

Relationship between Intrusions and Mineralization

Lithology
350 to 250 RL

Ore Zones
290 to 280 RL

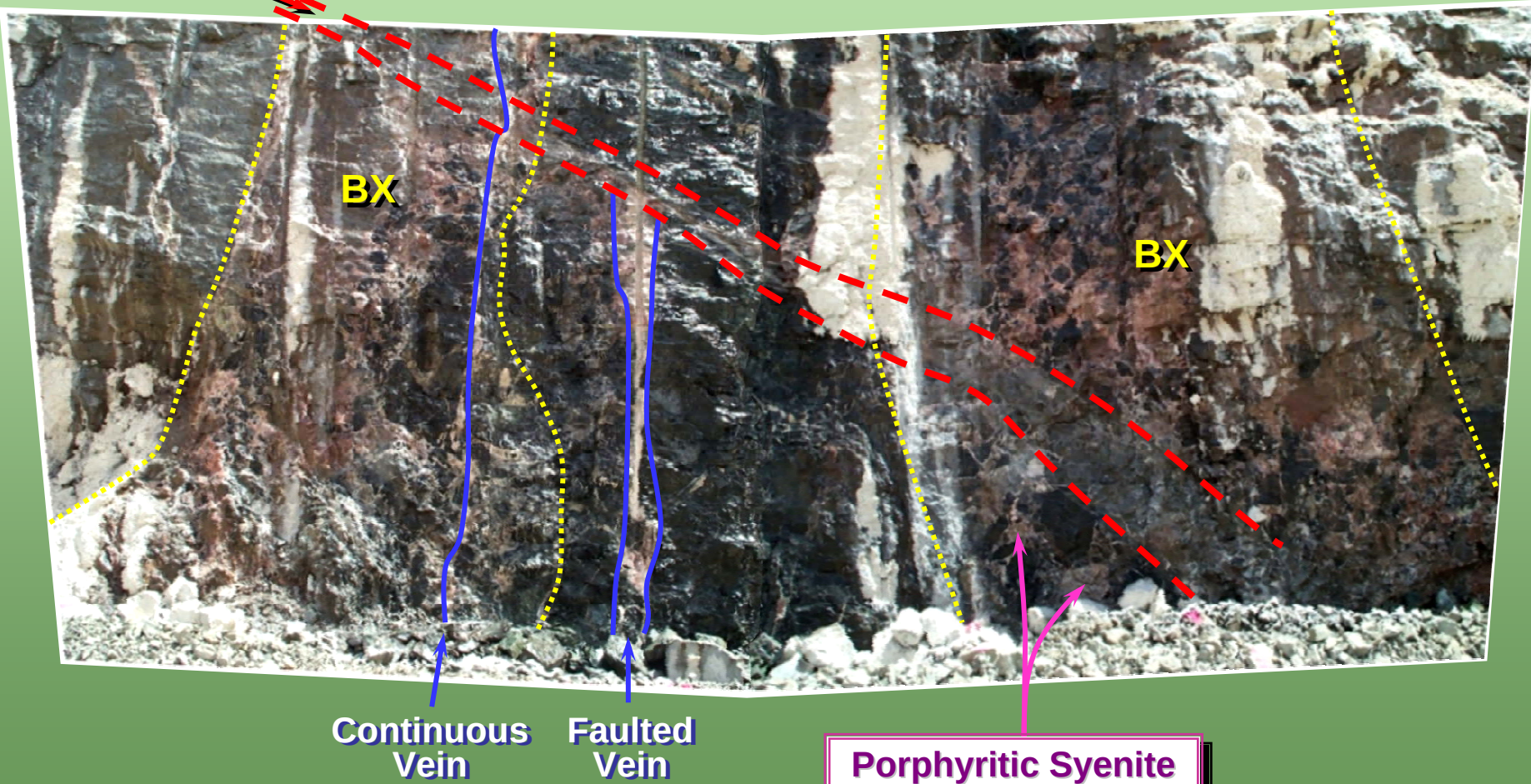
500m



Breccia Pipes

260 RL

Ore Zone



Continuous
Vein

Faulted
Vein

Porphyritic Syenite

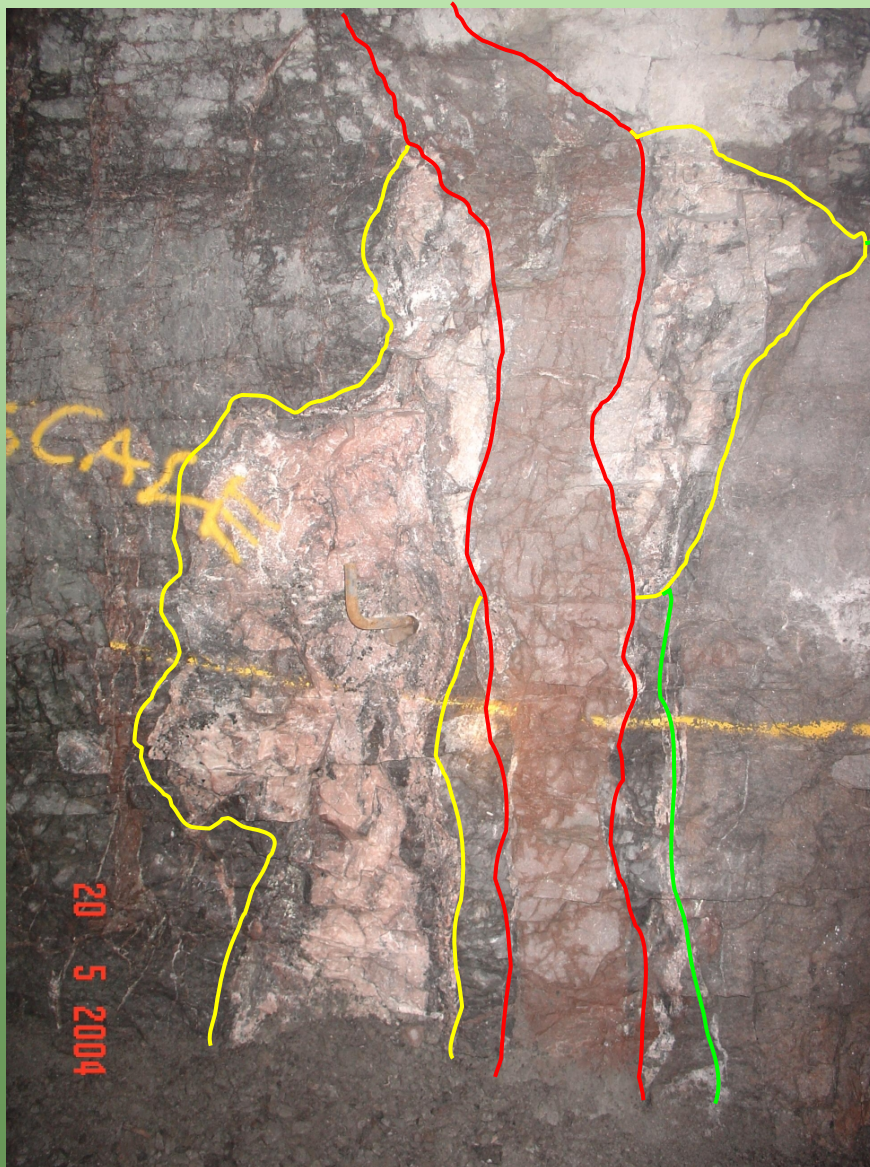
Breccia Pipe (260 RL)



The photograph shows a vertical rock face with a breccia pipe structure. A red dashed line outlines a central zone, and a red bracket on the right identifies it as the 'Ore Zone'. At the bottom, a pink arrow points to a specific rock type, identified as 'Porphyritic Syenite'.

Ore Zone

Porphyritic Syenite



Paragenetic Sequence:

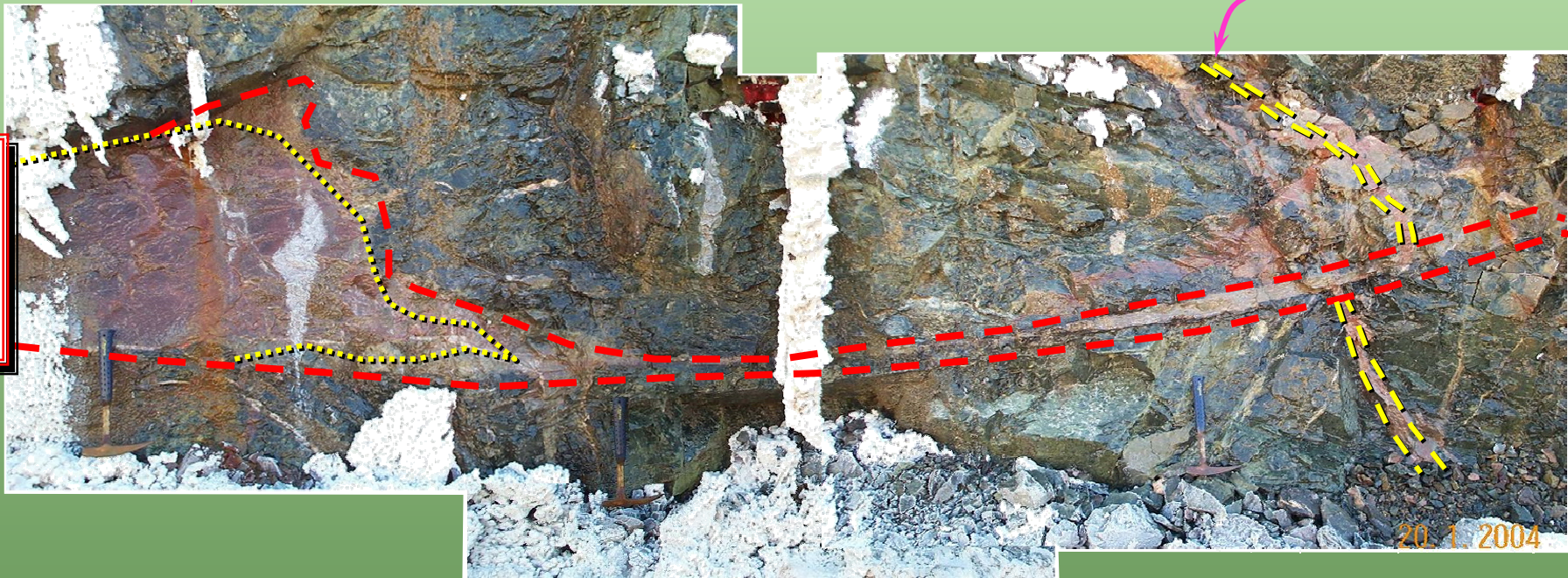
1. Syenite porphyry (green) intrudes conglomerate.
2. Carbonate-feldspar-biotite-pyrite-magnetite "vein" (yellow) intrudes. Biotite overprints porphyry for 10cm along contact.
3. Hematized syenite dyke (red) crosscuts magmatic carbonate vein.

Syenite Intruding an Ore Zone

Syenite Sill

Early Syenite Dike

Ore Zone



Early syenite dike (RHS) is crosscut and offset by ore zone.

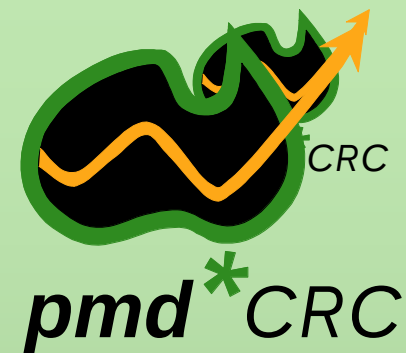
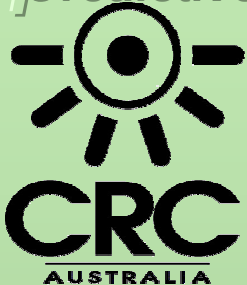
Late syenite sill (LHS) has intruded along the same structure that hosts the ore zone.

Preliminary Results

PROJECT	OUTCOMES
Structural Controls on Grade Distribution	• Highest gold grade occurs at inflection points in a ramp-flat geometry • Allows better constraints for open pit mining methods • Provides confidence in the models used to develop underground mining operations
Chemical Controls on Grade Distribution	• Genetic model—fluid mixing scenarios versus sulfidation reactions • Feeds back into mining methods • Feeds back into the exploration model
Ore and Intrusive Relationships	• Better constraints on geochronology samples • Genetic model for the formation of Wallaby • Exploration model → Which, if any, intrusive phases are important?

Wallaby Stage 2 Mining





Integration Y3 – M358

Peter Neumayr¹, John Walshe²

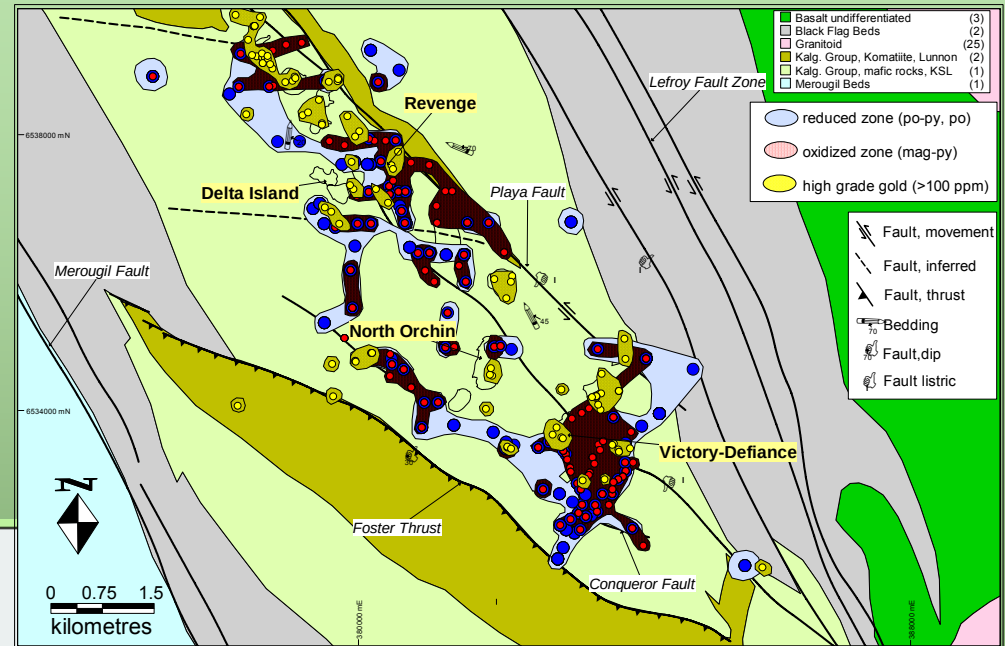
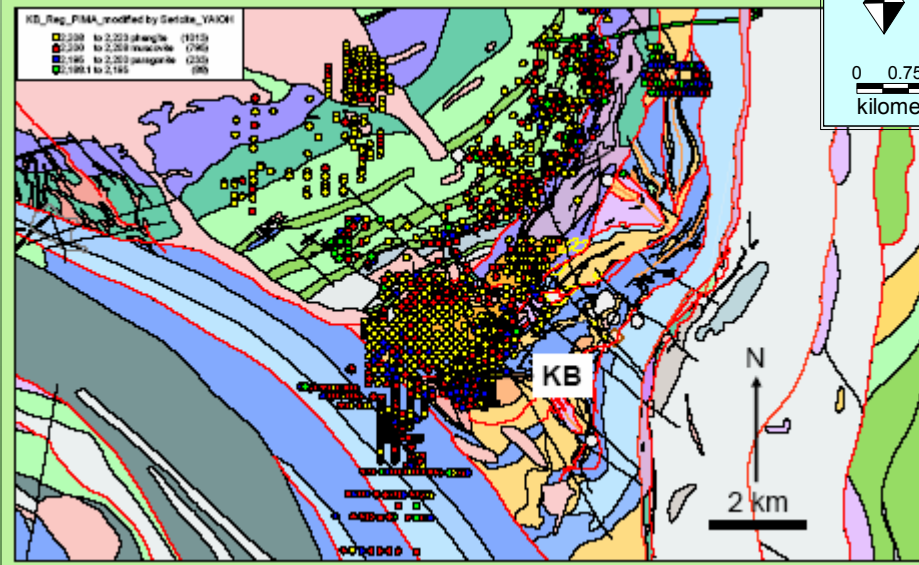
¹ Centre for Global Metallogeny, UWA

² CSIRO, Division of Exploration and Mining

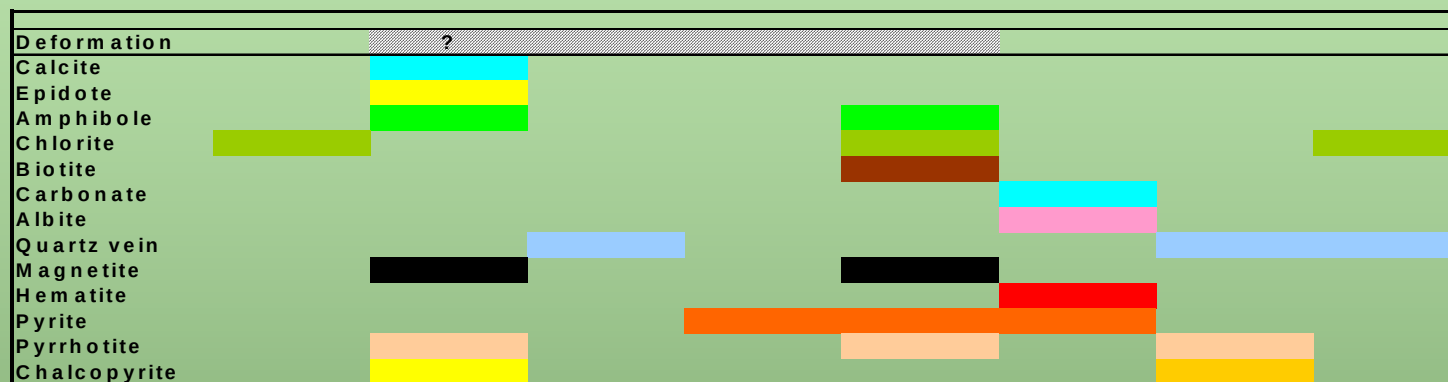


Chemical Gradients

Kanowna Belle



Comparative Temporal Evolution



St. Ives

Au

Early Fluid Cycle

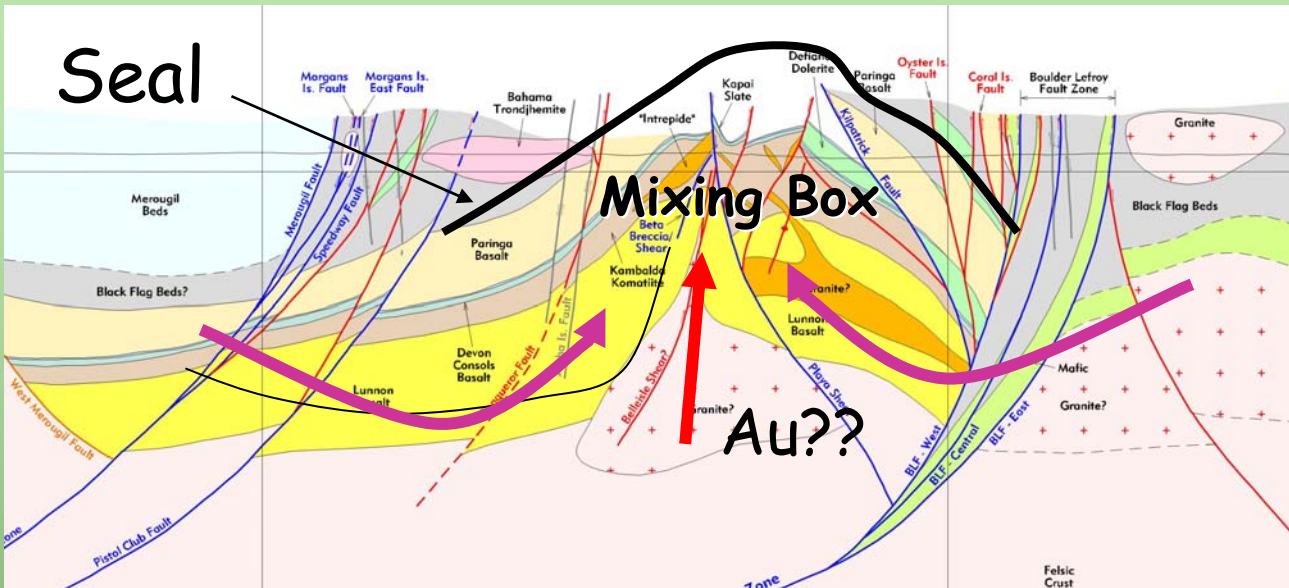
Intermed. Fluid Cycle

Late Fluid Cycle

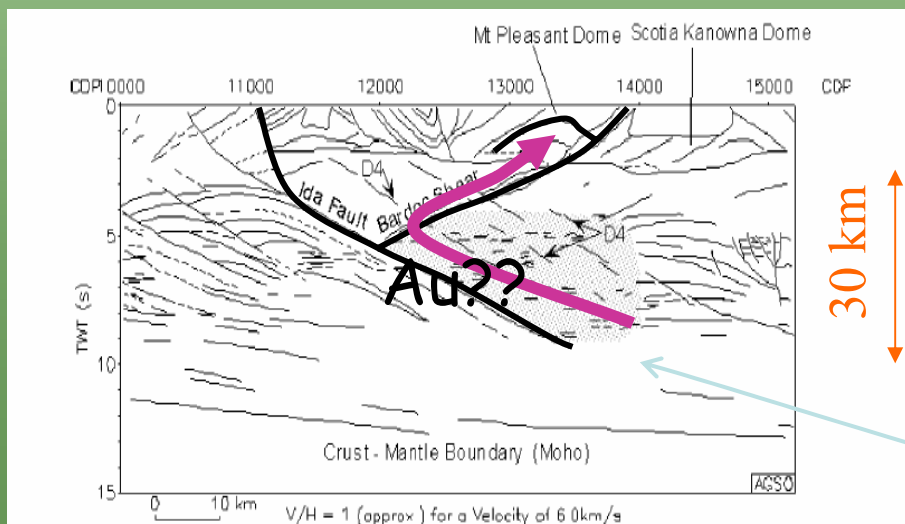
Ep-Act-Mag
Wallaby Pipe

Au Stage
Wallaby Pipe

Predictive Mineral Discovery Archean Au Systems



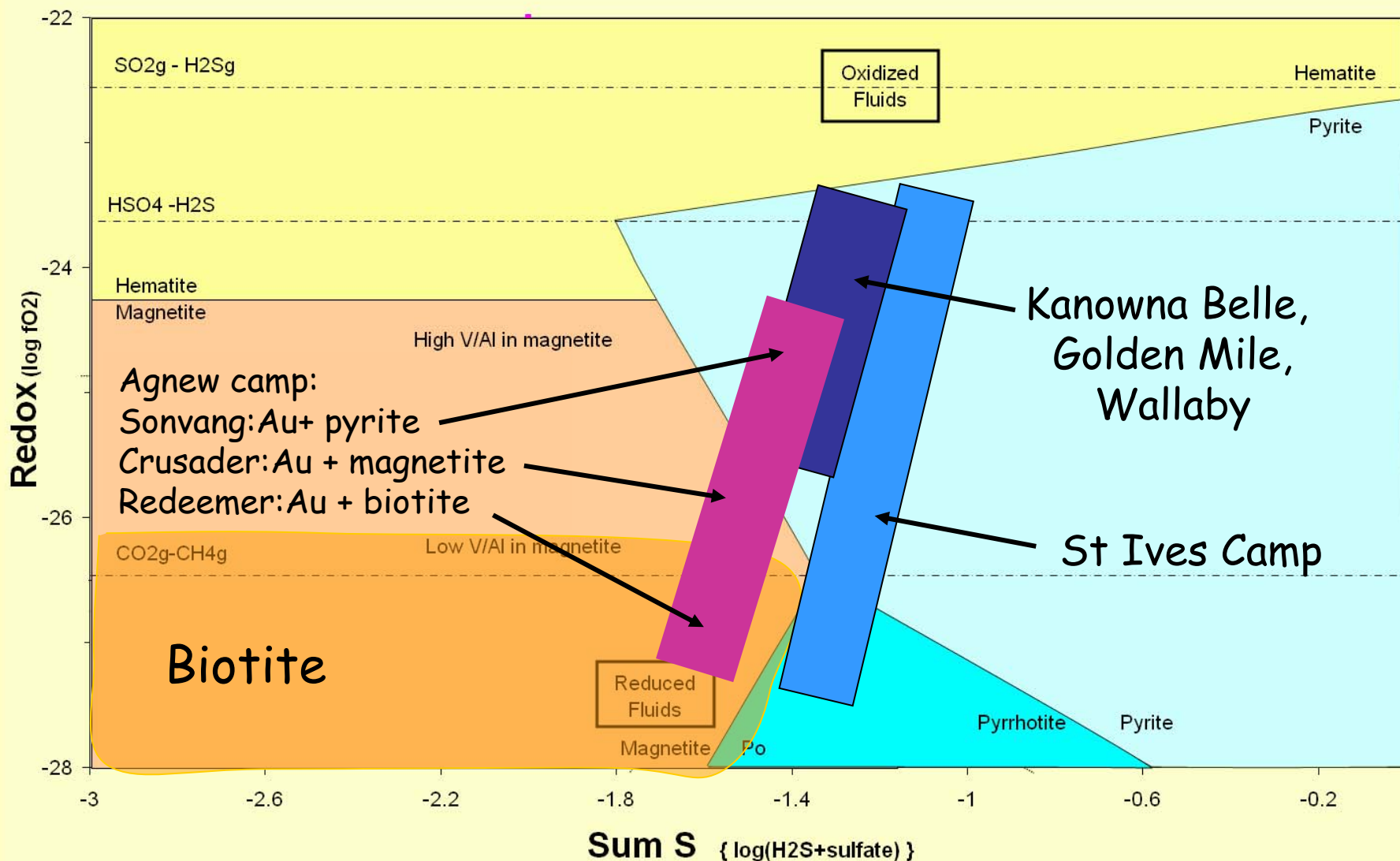
Upper-crustal System



Whole - crustal System

What came up the big crack ??

Conditions of Gold Deposition



Integration

- Spatial
 - Deposit to camp
 - Beyond camp
- Temporal Sequence
- Architecture
- Technological
- Conceptual