The Liquid Bismuth Collector Model: An Analysis of the Stormont Au-Bi Prospect, Tasmania

Amy Cockerton

Masters Preliminary Project Results

Supervisor: Dr Andy Tomkins, Monash University

Introduction

The study of fluid flow processes remains vital in the pursuit of understanding ore deposit formation.

A new hypothesis for the “Liquid Bismuth Collector Model”, was proposed by Douglas et al. 2000, pertaining to the influence of bismuth in hydrothermal fluids containing gold.

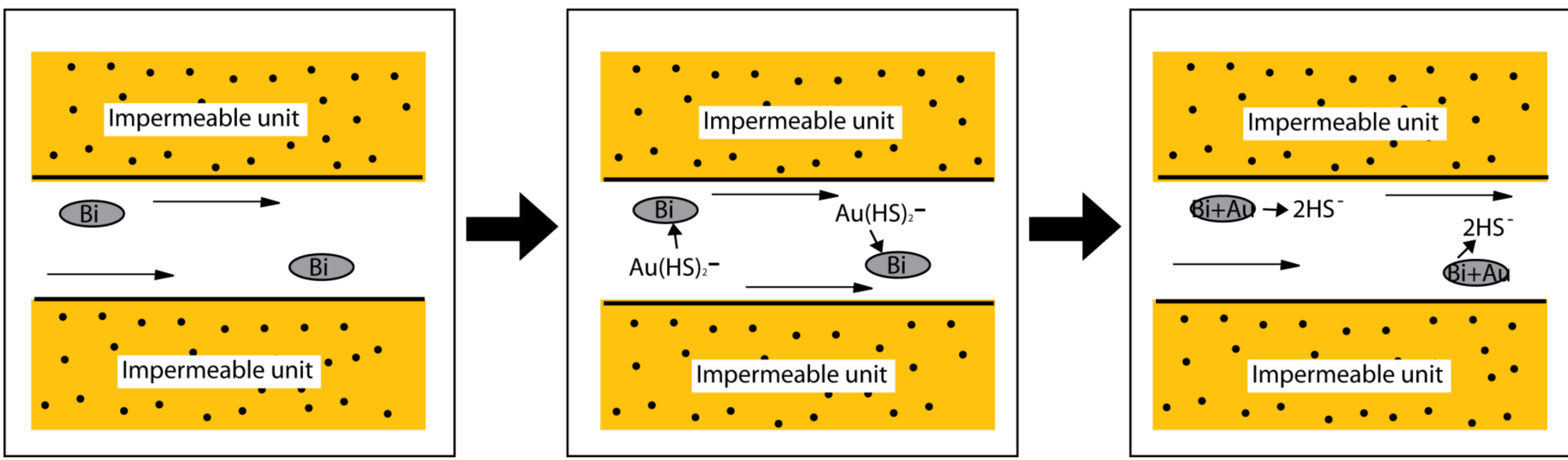
This new study outlined three main factors:

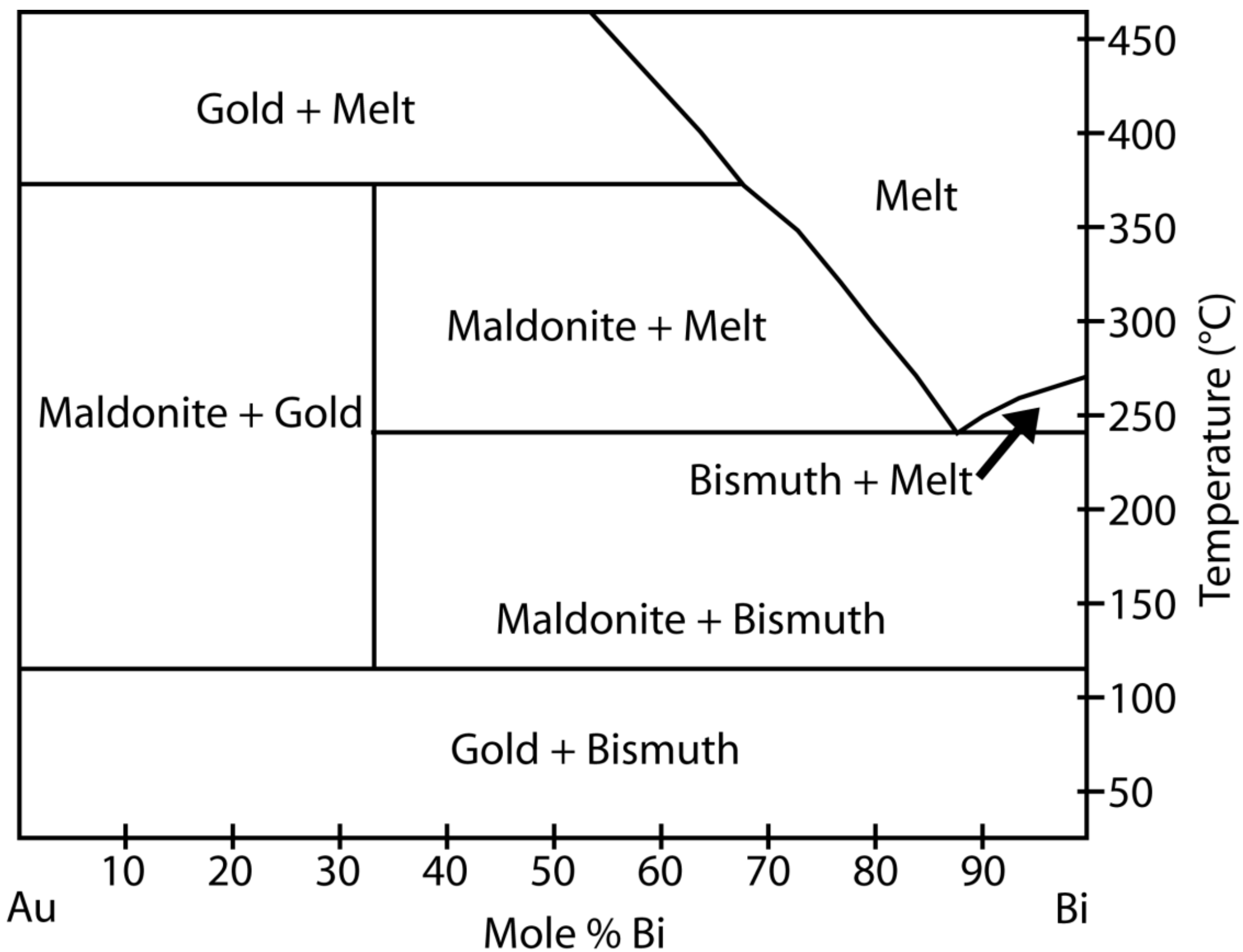
→ Bismuth has a very **low melting temperature of 271°C**

→ **Bismuth and gold have a close chemical affinity** and thermodynamic relationship

→ Due to this relationship, given temperatures in excess of 271°C and bismuth-saturated hydrothermal fluid, **bismuth will precipitate as a melt amongst that fluid**, and the **liquid bismuth will scavenge ionic gold from the fluid regardless of the concentration of gold**.

The Liquid Bismuth Collector Model





Phase diagram for Au-Bi system at 1 bar adapted from Tooth *et al. (2008) and experimental data input from Nathans and Leider (1962)*

This was supplemented by studies by:

- Tooth et al, 2008 in *Geology* which further defined the chemical conditions required for a liquid bismuth melt, and
- Ciobanu et al, 2010 in *Lithos* which outlined Au-Bi-Te-S associations at the Maldon deposit, Victoria.

maldonite (gold-bismuth alloy) = Au_2Bi

Project Aims

To test if this hypothesis for a “Liquid Bismuth Collector Model” can apply to real-life environments, not just thermodynamic models

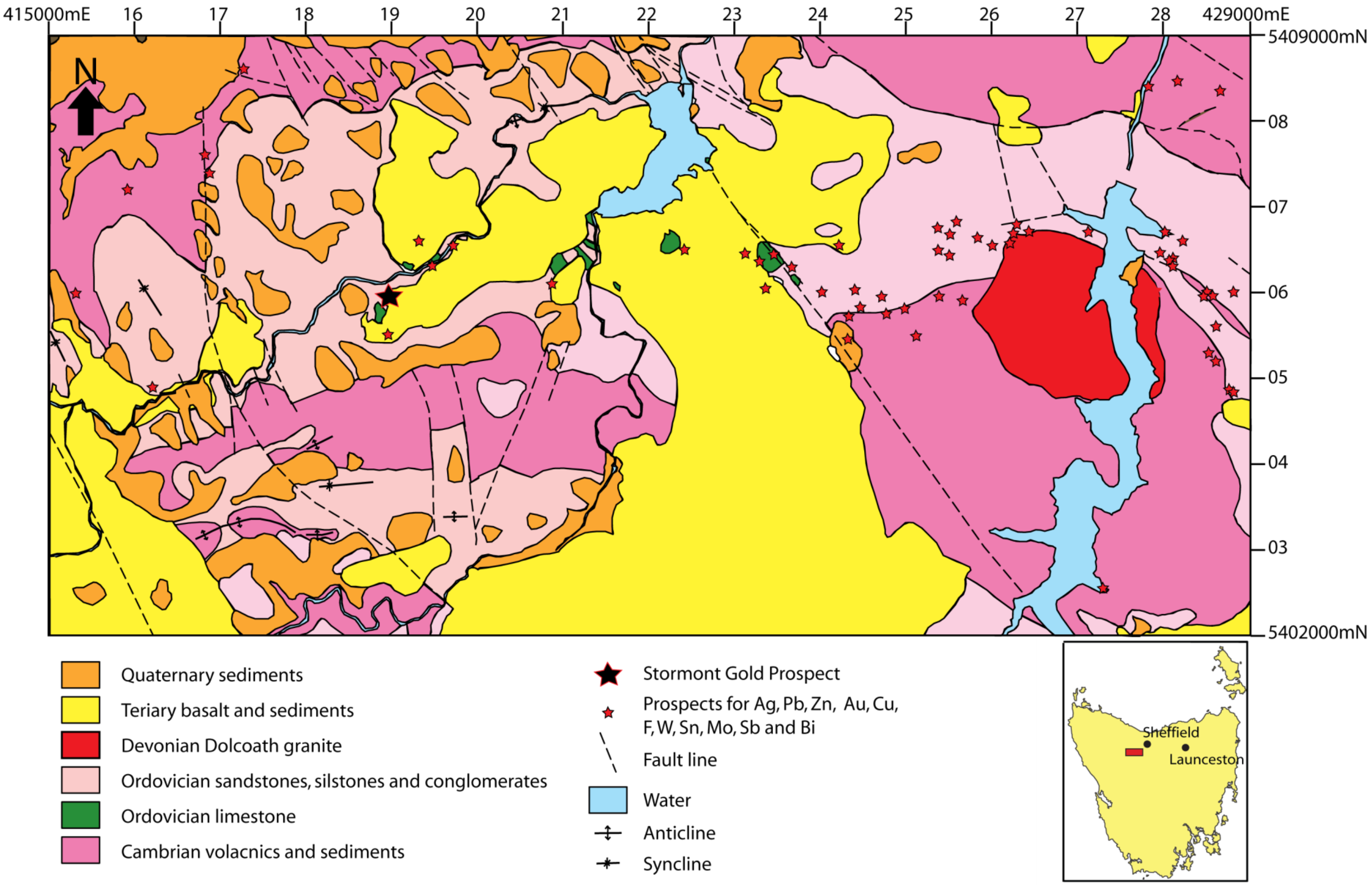
In order to test this model, we aim to:

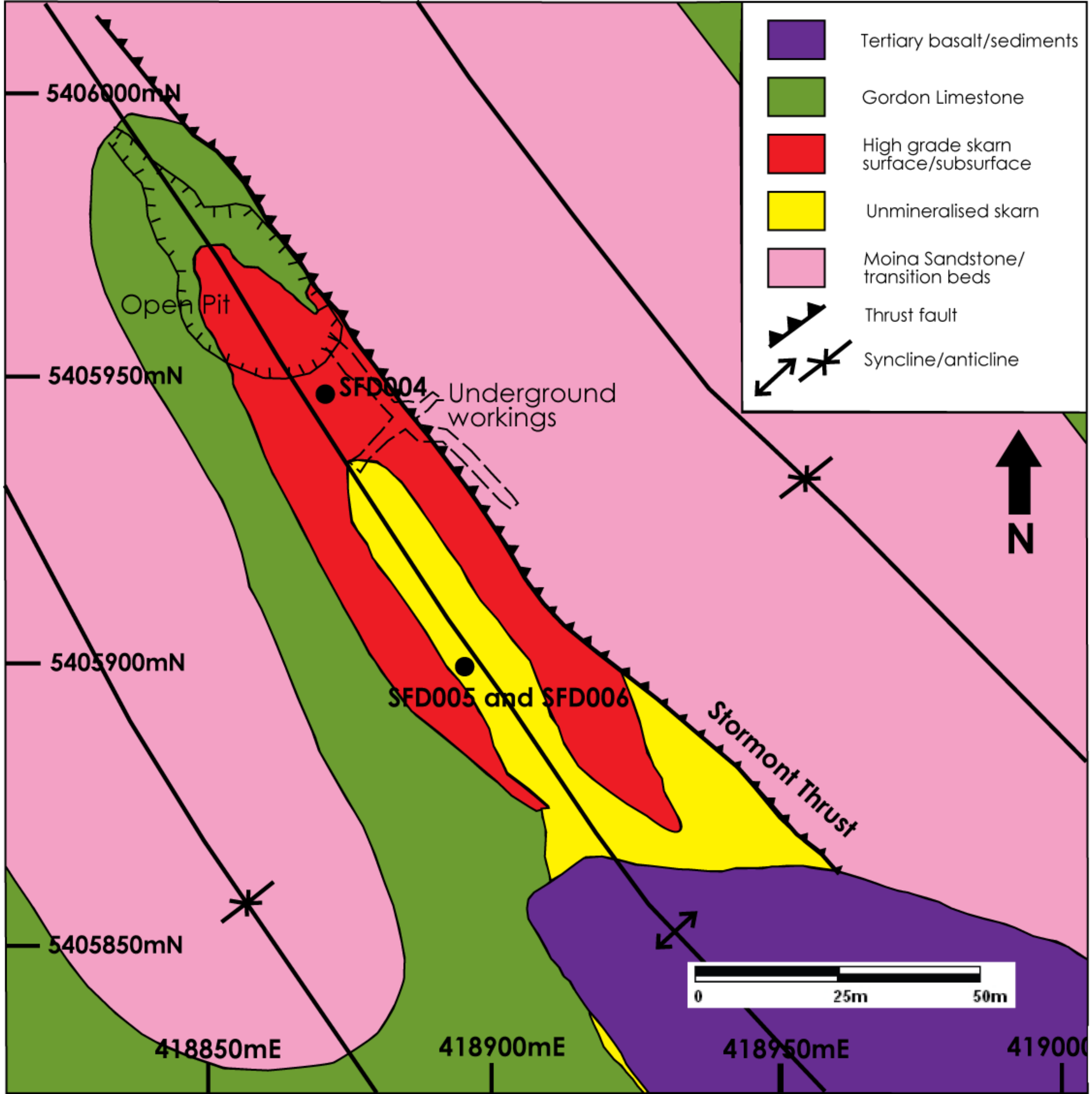
- Analyse the mineralisation conditions at Stormont, Tasmania to and interpret whether they were conducive to the model
- Conduct temperature experiments to further negate or corroborate the interpretations

Methodology

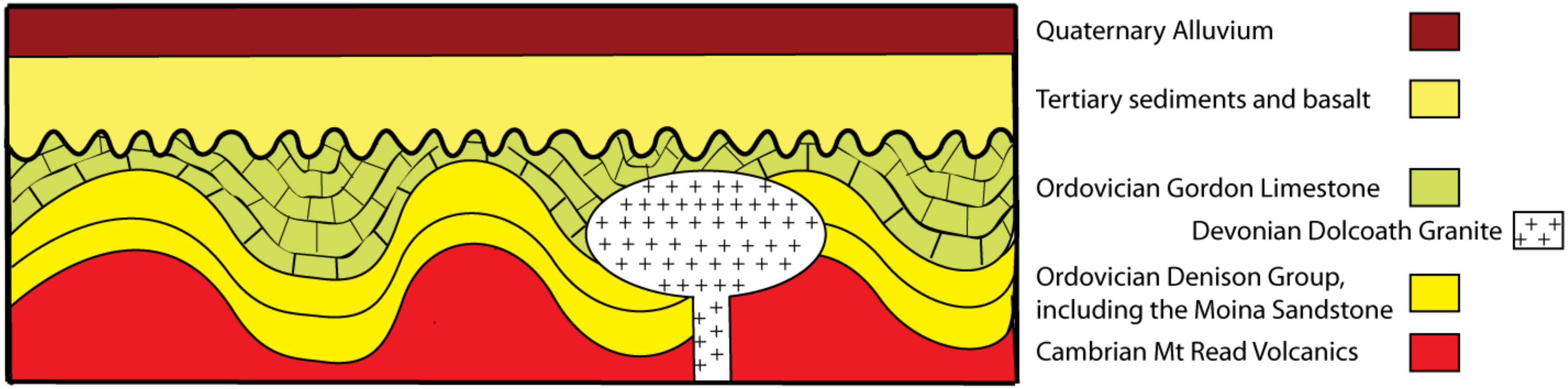
- Sampling from the Stormont skarn
- Analysis of textures and mineralogy from thin sections using optical microscope, SEM-EDS and electron microprobe techniques
- Analysis of geochemical assays provided by Frontier Resources
- Fluid inclusions experiments
- Bismuth inclusions experiments
- Temperature & pressure experiments

Regional Geology of Stormont





Tertiary basalt/sediments
Gordon Limestone
High grade skarn surface/subsurface
Unmineralised skarn
Moina Sandstone/ transition beds
Thrust fault
Syncline/anticline
5406000mN
5405950mN
5405900mN
5405850mN
418850mE
418900mE
418950mE
Open Pit
SFD004
Underground workings
SFD005 and SFD006
Stormont Thrust
N
0
25m
50m



Schematic diagram of the stratigraphy at, and surrounding Stormont

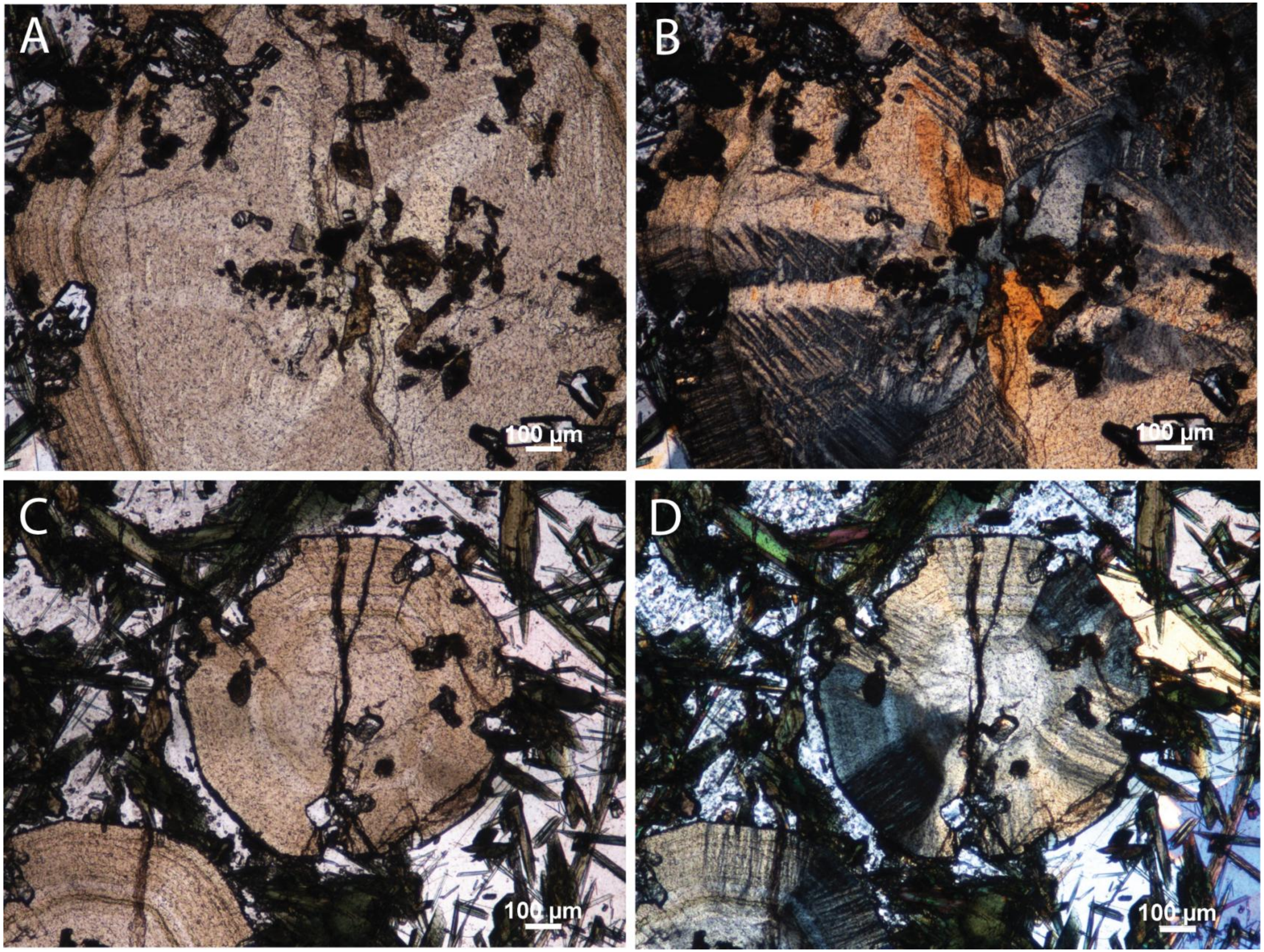
Main periods of tectonic activity include:

- The Cambrian Tyennan Orogeny
- Tabberabberan Orogeny-related Devonian convergence
- Late Devonian Dolcoath Granite emplacement

Results and interpretations

Silicate mineral assemblage of fine-grained:

- Actinolite
- Quartz
- Calcite
- Grandite (calcic garnet)
- Epidote
- Hedenbergite (Fe-rich endmember of diopside)

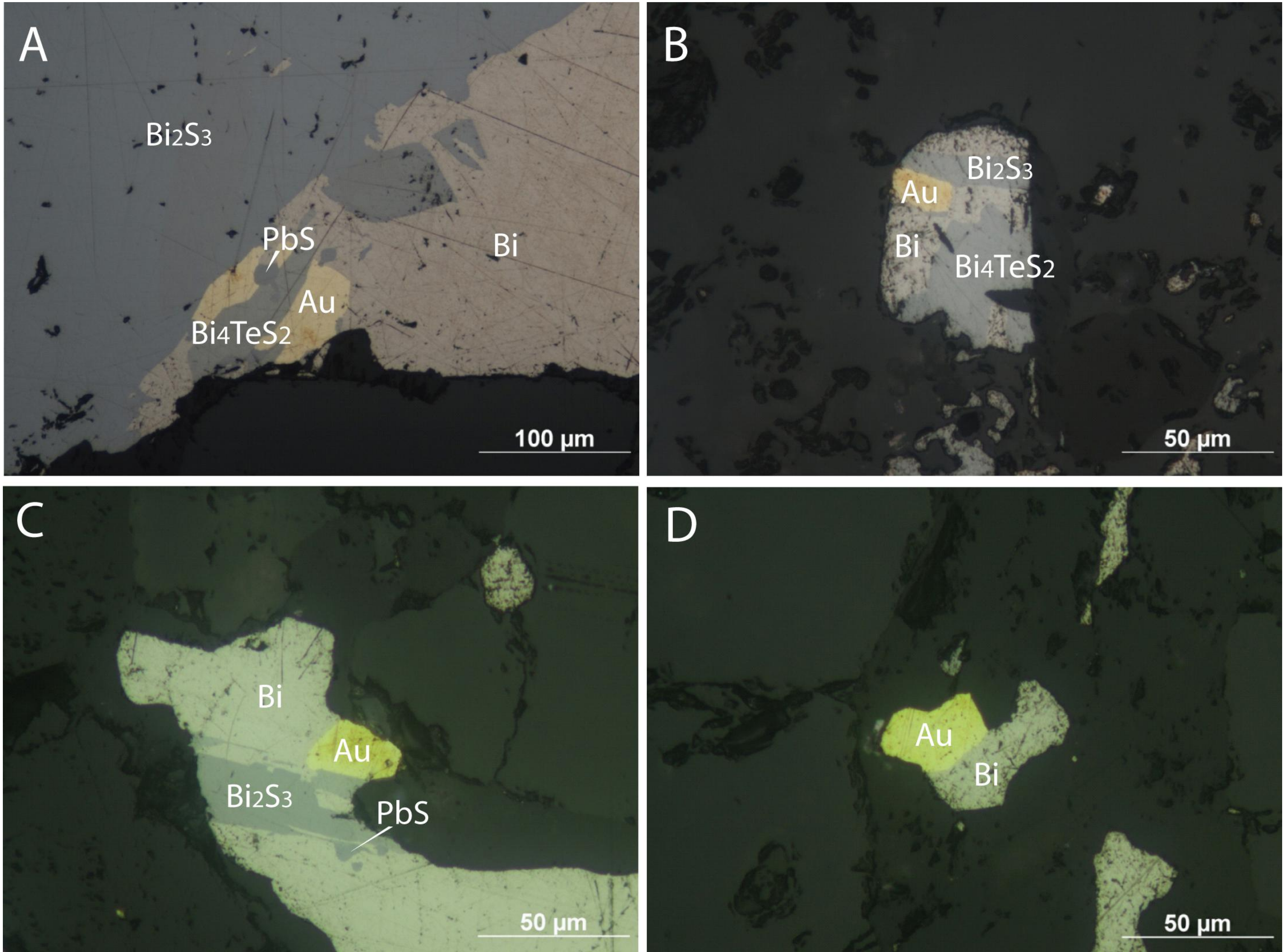


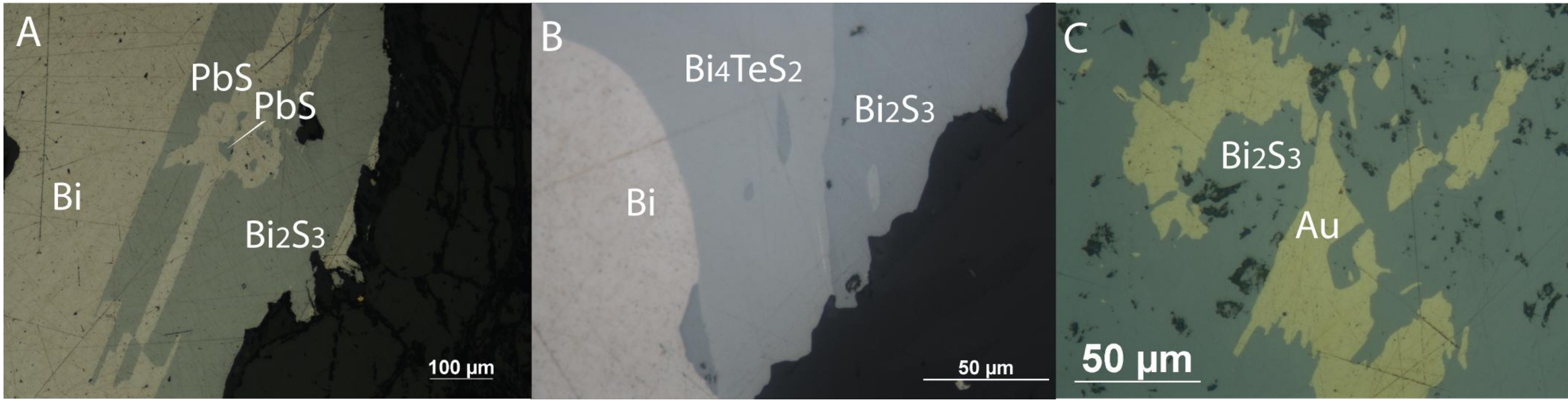
Photographs of zoned garnets viewed by an optical microscope. A) & C) use plane polarised light and B) & D) are the corresponding cross-polarised light photographs. Note the zoning, perthitic textures, sector twins and strong anisotropy.

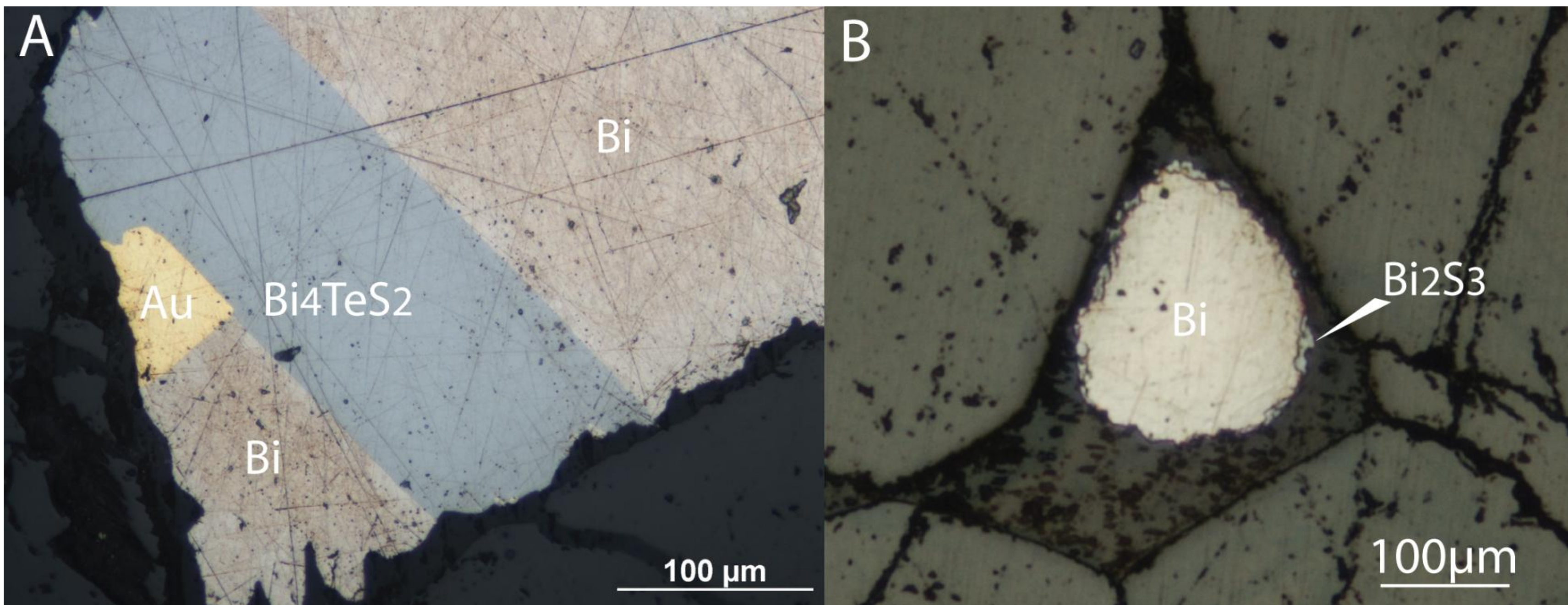
Ore mineral assemblage of fine-grained:

- Native bismuth
- Native gold (with up to 20% Ag)
- Bismuthinite (Bi_2S_3; with up to 8% Pb)
- Galena
- Protojoseite (Bi_4TeS_2; with up to 4% Pb)
- Maldonite (Au_2Bi)

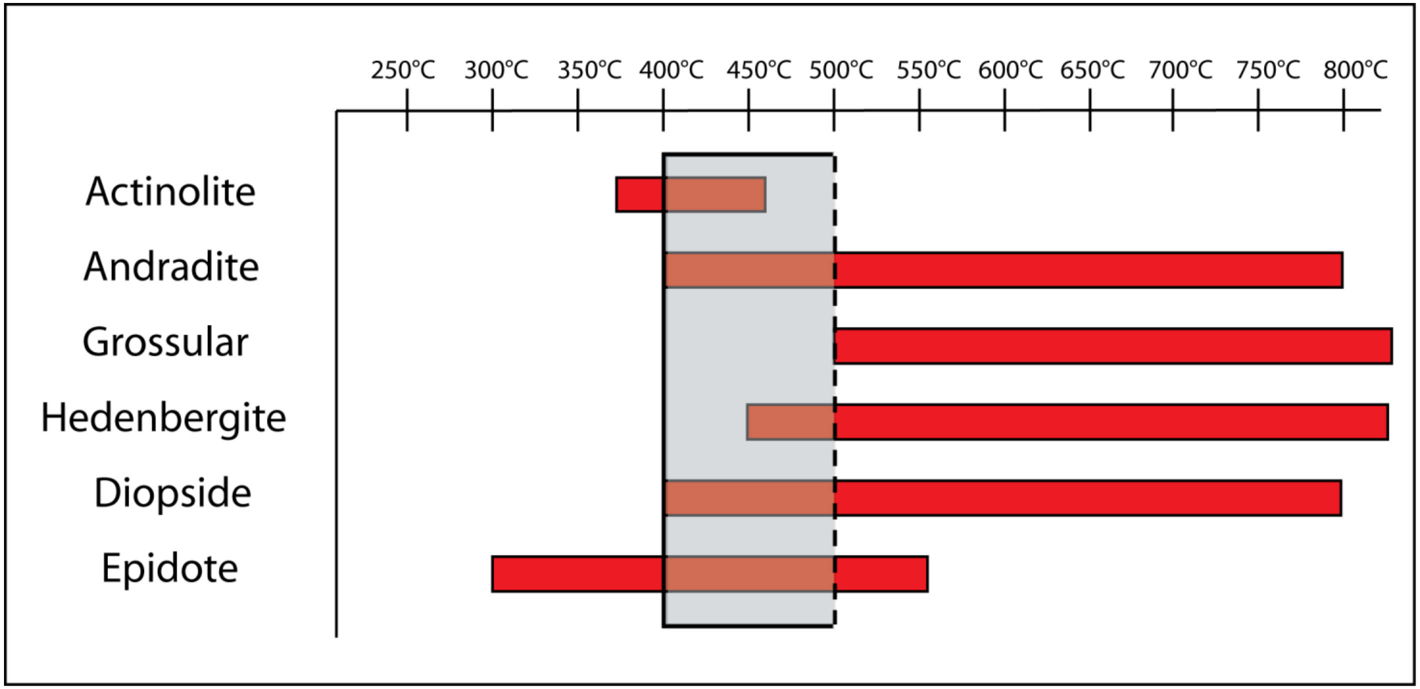
Ore minerals are found in mostly grandite-dominated domains, and sometimes in actinolite-dominated and in mixed silicate domains.


A
Bi2S3
PbS
Bi
Au
Bi4TeS2
100 μm
B
Bi2S3
Au
Bi
Bi4TeS2
50 μm
C
Bi
Au
Bi2S3
PbS
50 μm
D
Au
Bi
50 μm


A
PbS
PbS
Bi
Bi2S3
100 µm
B
Bi4TeS2
Bi2S3
Bi
50 µm
C
Bi2S3
Au
50 µm

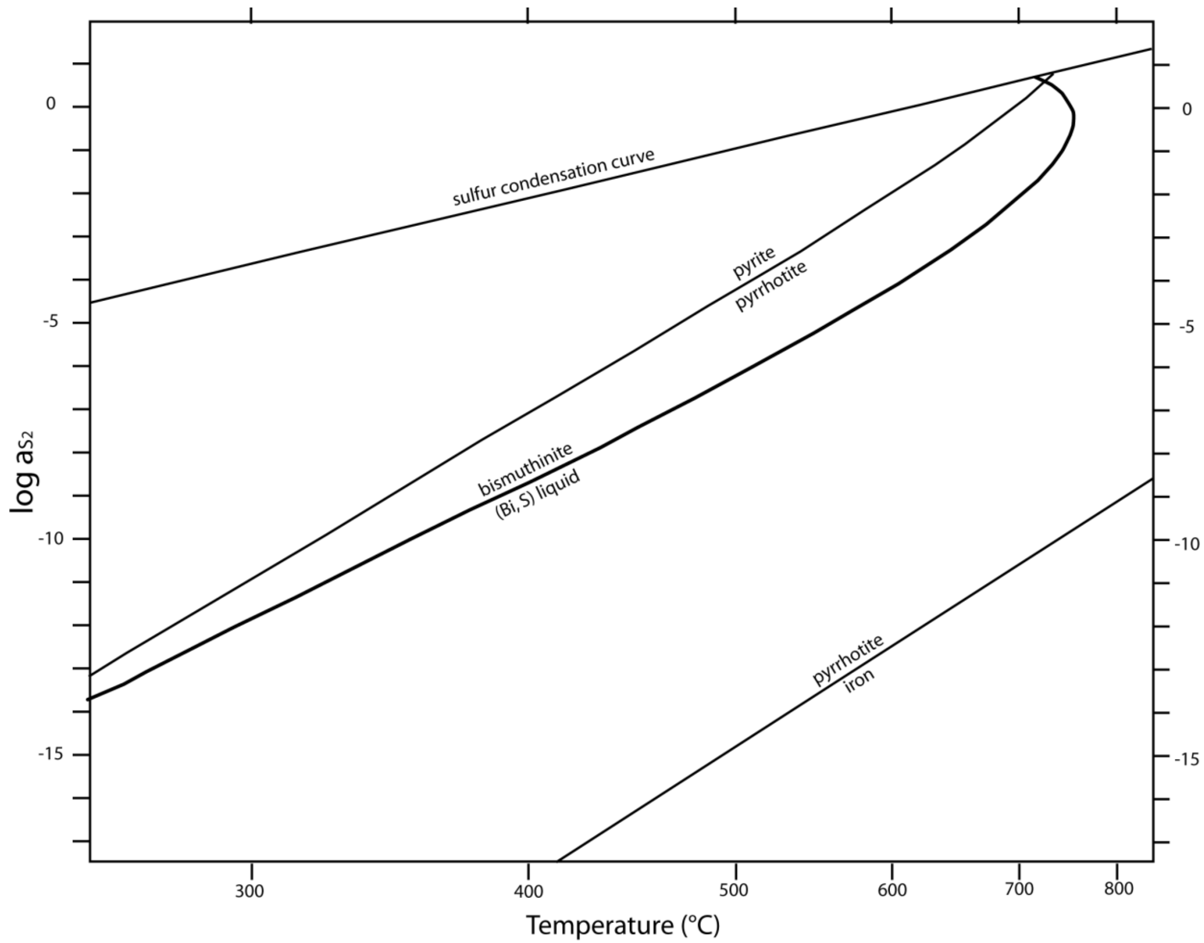

A
Bi
Au
Bi4TeS2
Bi
100 µm
B
Bi2S3
Bi
100µm

From the silicate mineralogy and related studies on each silicate mineral, an estimated temperature of ore mineralisation was found to be >400°C → well within the limits of the model



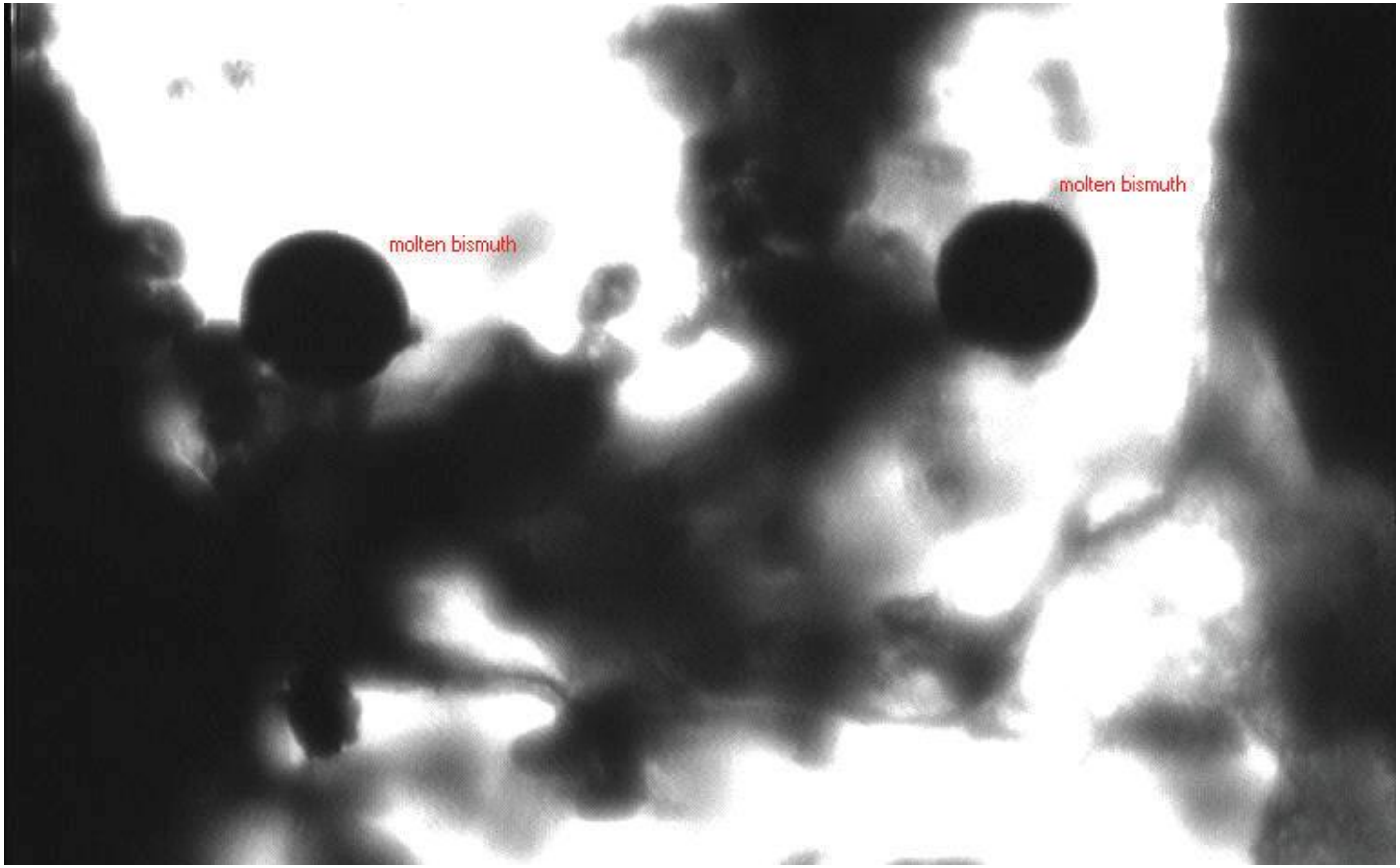
Low sulphur. Reduced conditions.

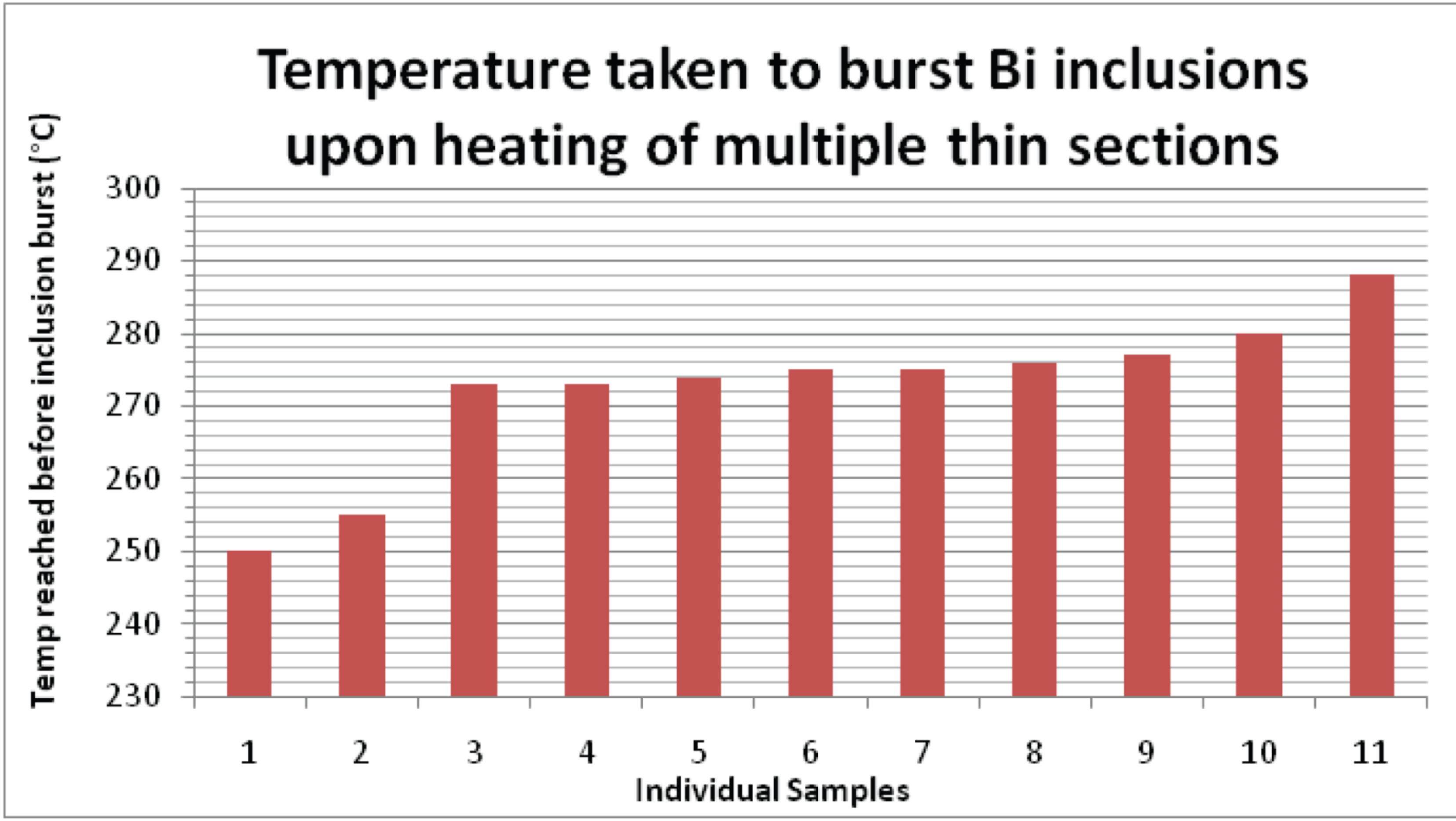
•Native bismuth and bismuthinite often occupy the same metallic accumulation, and some bismuth grains have small rims of bismuthinite
•This indicates an environment with relatively low sulfur content that that a the system cooled bismuthinite became the more stable mineral.



Bismuth inclusion experiments:

- Heated doubly polished thin sections with bismuth inclusions encapsulated in grandite crystals
- Inclusions near the surface of the thin sections, will burst upon melting due to the positive volume change from solid to liquid
- This leaves a spherical liquid droplet on the surface of the thin section




Temperature taken to burst Bi inclusions upon heating of multiple thin sections
Temp reached before inclusion burst (°C)
300
290
280
270
260
250
240
230
1
2
3
4
5
6
7
8
9
10
11
Individual Samples

Therefore, from the mineralogy, combined with the bismuth inclusion experiments, we can conclude that the **conditions were suitable for a liquid bismuth melt**, and given the spatial correlation, it appears to have scavenged gold at Stormont.

Now that we have established that the Liquid Bismuth Collector Model had likely occurred at Stormont, we looked to investigate the efficiency of the model…

Secondary aims:

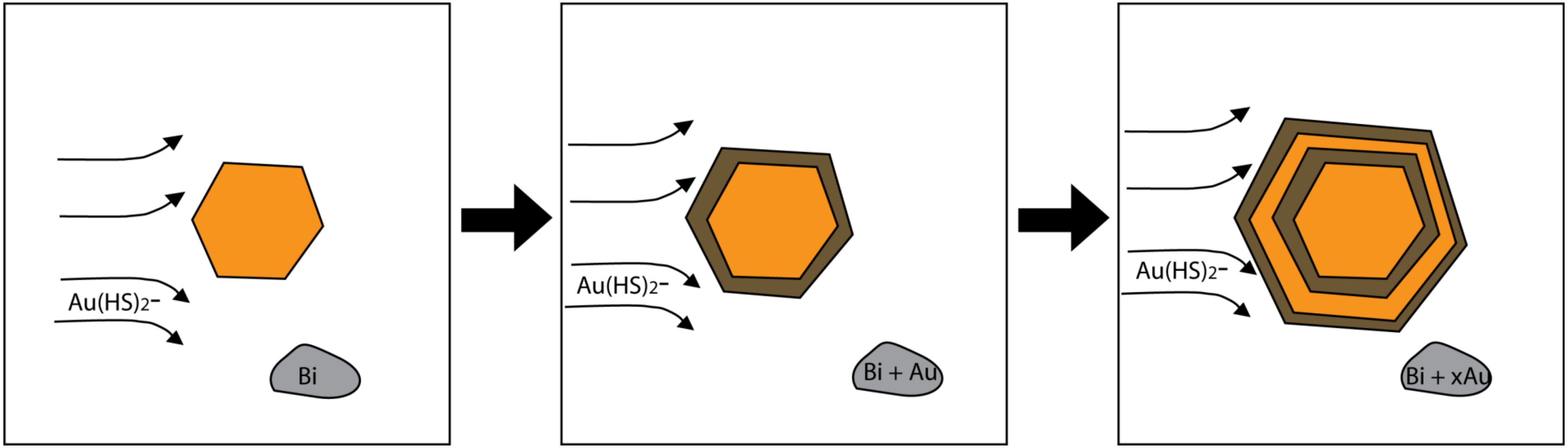
- To investigate the efficiency of the Liquid bismuth collector model at Stormont
- Determine the ideal conditions for maximum efficiency.

The zoning in garnets indicates repeated fluid fluxes of alternating composition
→ therefore, there were multiple fluid flow events
→ therefore, a relatively high volume of fluid passed by these garnets in order to have formed the strong zonation.

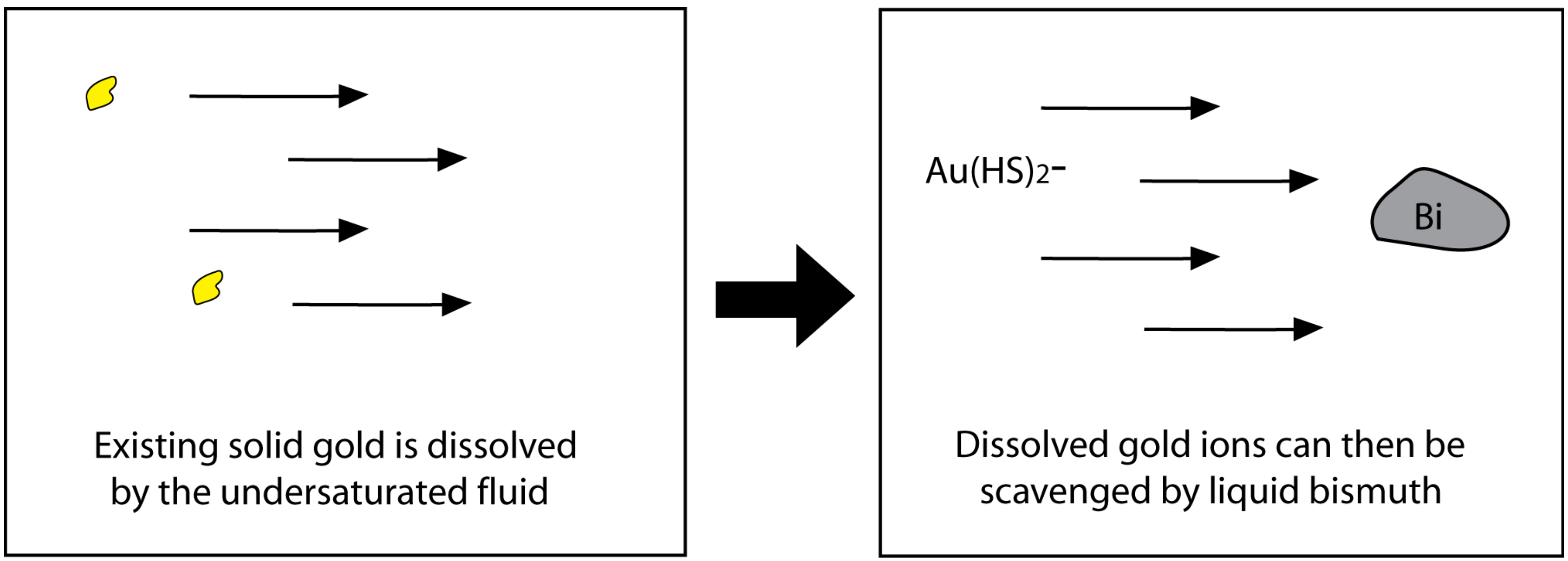
With high volumes of fluid comes increased efficiency of the bismuth scavenging system

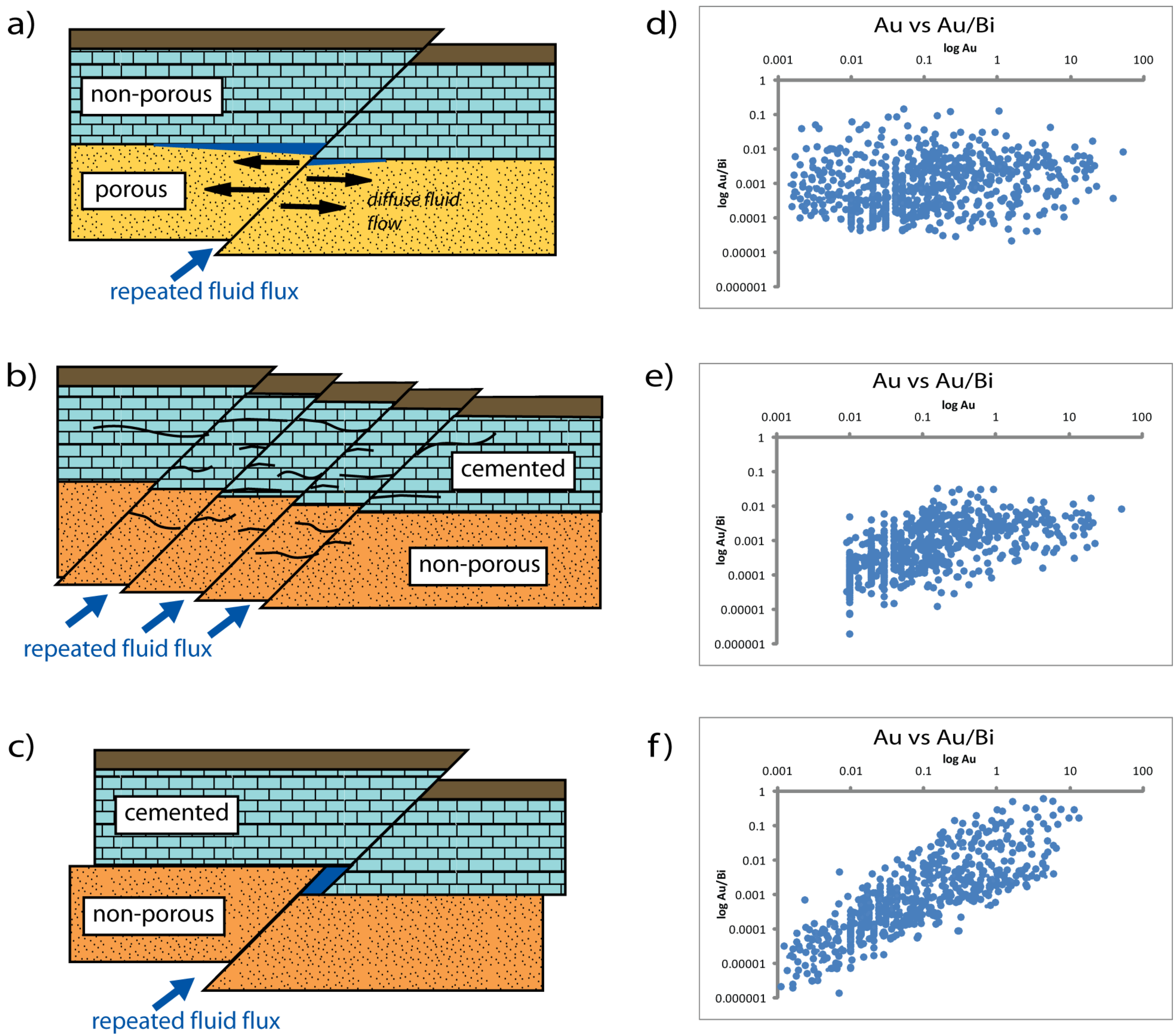
•Liquid bismuth + repeated fluid interaction = more fluids from which to potentially scavenge gold

Therefore this would facilitate a gold refining process.



Zone refinement of gold




a)
non-porous
porous
diffuse fluid flow
repeated fluid flux
b)
cemented
non-porous
repeated fluid flux
c)
cemented
non-porous
repeated fluid flux
d)
Au vs Au/Bi
log Au
log Au/Bi
e)
Au vs Au/Bi
log Au
log Au/Bi
f)
Au vs Au/Bi
log Au
log Au/Bi
0.001
0.01
0.1
1
10
100
0.0001
0.00001
0.000001

Time, fluid volume, the amount of available bismuth, the existence or lack of focused fluid flow and the amount of ionic gold in hydrothermal fluid, all influence the efficiency of the LBCM.

Therefore large, deeply emplaced intrusions with focused fluid flow structures may be an ideal environment for bismuth-derived gold refinement to occur.

Stormont was an IRG prospect however orogenic and VMS type deposits may also be viable sites for bismuth scavenging to have occurred.

Conclusions

- The evidence strongly suggests that during mineralisation, Stormont had a liquid bismuth melt which scavenged gold.
- The efficiency of the model can be enhanced by: high fluid flux volume, a prolonged mineralisation duration, high available bismuth (ie not locked up in bismuthinite), focused fluid flow structures, and high concentration of ionic gold.

What this all means for exploration:

- Exploration geologists should now also look at lower temperature hydrothermal systems if they also contain bismuth.
- This may mean that target areas may be widened as these systems can form further away from heat sources than traditional high temperature gold formation models.

References

- Ciobanu, C. L., Birch, W. D., Cook, N. J., Pring, A., and Grundler, P. V., 2010, Petrogenetic significance of Au-Bi-Te-S associations: The example of Maldon, Central Victorian gold province, Australia: Lithos, v. 116, p. 1-17.
- Douglas, N., Mavrogenes, J., Hack, A., and England, R., 2000, The liquid bismuth collector model: An alternative gold deposition mechanism: Understanding planet Earth; searching for a sustainable future; on the starting blocks of the third millennium: Australian Geological Convention, 15th, Sydney, 2000, p. 135.
- Tooth, B., Brugger, J., Ciobanu, C., and Liu, W., 2008, Modeling of gold scavenging by bismuth melts coexisting with hydrothermal fluids: Geology, v. 36, p. 815–818.

Questions?

For more information, contact me at:

amy.cockerton@monash.edu