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) = \( \text{Au}_2\text{Bi} \)
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

- Quaternary sediments
- Tertiary basalt and sediments
- Devonian Dolcoath granite
- Ordovician sandstones, siltstones and conglomerates
- Ordovician limestone
- Cambrian volcanics and sediments
- Stormont Gold Prospect
- Prospects for Ag, Pb, Zn, Au, Cu, F, W, Sn, Mo, Sb and Bi
- Fault line
- Water
- Anticline
- Syncline
Main periods of tectonic activity include:

• The Cambrian Tyennan Orogeny
• Tabberabberan Orogeny-related Devonian convergence
• Late Devonian Dolcoath Granite emplacement
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 ($\text{Bi}_2\text{S}_3$; with up to 8% Pb)
- Galena
- Protojoseite ($\text{Bi}_4\text{TeS}_2$; with up to 4% Pb)
- Maldonite ($\text{Au}_2\text{Bi}$)

Ore minerals are found in mostly grandite-dominated domains, and sometimes in actinolite-dominated and in mixed silicate domains.
From the silicate mineralogy and related studies on each silicate mineral, an estimated temperature of ore mineralisation was found to be $>400^\circ\text{C}$ → 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 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

<table>
<thead>
<tr>
<th>Individual Samples</th>
<th>Temp reached before inclusion burst (°C)</th>
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<tbody>
<tr>
<td>1</td>
<td>230</td>
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<tr>
<td>2</td>
<td>245</td>
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<tr>
<td>3</td>
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<td>10</td>
<td>300</td>
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<td>11</td>
<td>305</td>
</tr>
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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

Existing solid gold is dissolved by the undersaturated fluid

Dissolved gold ions can then be scavenged by liquid bismuth

Au(HS)₂⁻
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


Questions?

For more information, contact me at: amy.cockerton@monash.edu