Characterization and evolution of fluids associated with the Cu-Au deposit of the Ming Mine, Rambler area, northeast Newfoundland, Canada

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Summary

The volcanogenic massive sulphide (VMS) Cu±Zn-Au deposits in the Rambler area in northeast Newfoundland were formed in the Early Ordovician Pacquet Harbour Group. The area experienced upper greenschist facies metamorphism and multiple phases of deformation from Ordovician to post-Silurian time. Samples of ores were collected from the Ming Mine for petrographic and fluid-inclusion microthermometric studies in order to characterize the mineralizing fluids and to investigate the gold-rich nature of the mineralization. The samples are divided into primary ores (massive and stringer ores, least deformed) and secondary ores (syn- to post-deformation mineralization or deformed ores). Three types of fluid inclusions were recognized in the samples: aqueous, aqueo-carbonic, and carbonic. In the primary ores, all aqueo-carbonic inclusions are interpreted to be secondary, whereas many aqueous inclusions are primary, showing homogenization temperatures from 150°C to 275°C and salinities from 6 to 18$\%_{wt}$ NaCl equiv.. In the secondary ores, both aqueous and aqueo-carbonic primary inclusions are present, the former showing homogenization temperatures from 86°C to 305°C and salinities from 4 to 13$\%_{wt}$ NaCl equiv., and the latter having homogenization temperatures from 200°C to 375°C and salinities from 4 to 8$\%_{wt}$ NaCl equiv.. Fluid pressures calculated from the CO_2-bearing inclusions range from 500 bars to 3500 bars. The primary ores were interpreted to have formed from aqueous fluids derived from circulated seawater, whereas the fluids involved in the deformation and remobilization of the primary ores are of aqueous-carbonic composition suggesting metamorphic origins. The CO_2-bearing fluids are interpreted to be at least partly responsible for the enrichment of gold in the VMS deposits, although the possibility of gold enrichment associated with aqueous fluids during primary VMS mineralization cannot be ruled out.

Introduction

The volcanogenic massive sulphide (VMS) Cu-Au deposits in the Rambler area in northeast Newfoundland are enriched in gold and are classified as the Au-rich VMS type (Dubé et al., 2005). An understanding of the nature of gold enrichment is of interest for exploration for gold-rich VMS ores and potentially for gold mineralization outside the VMS deposits. We approach this problem from analysis of fluid inclusions in the ores, which can provide information about the composition, temperature and pressure of the fluids during primary VMS mineralization as well as those involved in subsequent reworking of the ores during deformation and metamorphism. These data are used to infer the nature of the fluids involved in the different stages of mineralization and shed light on the potential mechanisms of gold enrichment.

Geologic Setting

The Rambler area is located on Baie Verte Peninsula in northwestern Newfoundland. It contains several Cu±Zn-Au deposits, including the Ming Mine Cu-Au deposit (Fig. 1), from which the samples for the present study were collected. The ore zones occur at the top of the ca. 489 – 487 Ma Rambler rhyolite, which is underlain by boninites and overlain by a cap of magnetic chert or banded iron formation (locally rich in precious metals), which is in turn overlain by ca. 476 – 467 Ma tholeiitic basalts (Skulski et al., 2009). These units were subsequently intruded by post-mineralization tholeiitic gabbros which are suggested to be genetically related to the basalt sequence, and by several large Silurian granitoid intrusions including the ca. 446-430 Ma Burlington granodiorite, the ca. 436 Ma Cape Brule porphyry, and the ca. 429 Ma Dunamagon granite (Fig. 1; Skulski et al., 2009). The area has experienced inhomogeneous upper greenschist facies metamorphism and multiple deformational events from Ordovician to post-Silurian (Tuach and Kennedy, 1978; Skulski et al., 2009).

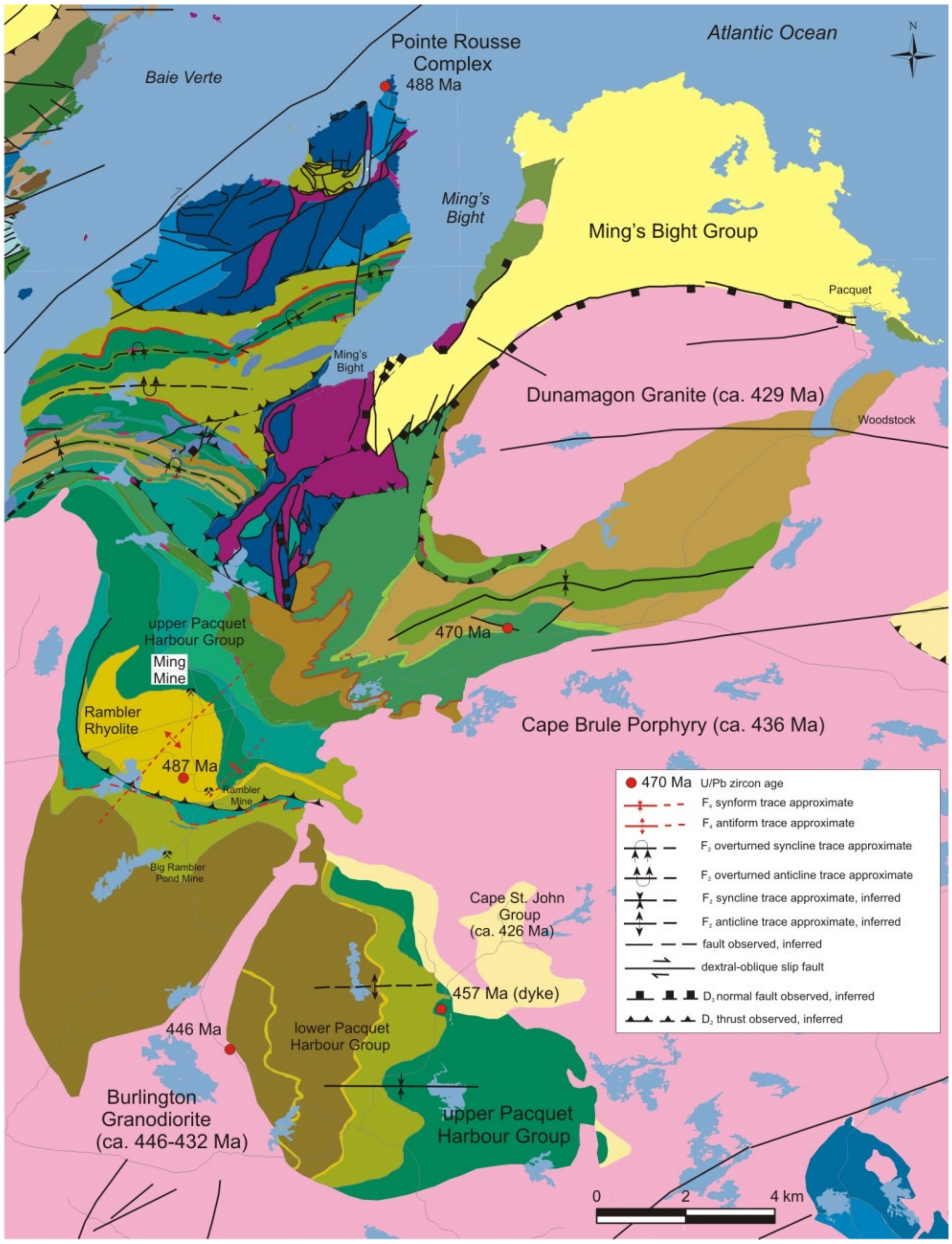

Figure 1. Geologic map of Baie Verte Peninsula, Newfoundland, showing the location of the Ming Mine and approximate ages of rocks and structural features (modified from Skulski et al., 2009).

Ore Petrography and Fluid-inclusion Microthermometry

A number of samples were collected from two drill cores from the Ming Mine, ranging from the footwall (stockwork ore zone), massive ore zone, to the hanging wall. Seven samples were selected for fluid inclusion studies, and were divided into four types: 1) massive sulphide ore that shows little deformation (Fig. 2A), 2) sulphide-quartz veins and veinlets in host rocks underlying the massive ore (the stringer zone) that show little evidence of deformation, 3) sulphide-quartz veins and veinlets that are stretched and compressed along foliation planes (Fig. 2B), and 4) sulphide-quartz veins that cut foliation planes. Types 1 and 2 samples are called primary ore, and 3 and 4 are called secondary ore, for simplicity of description and discussion.

Three types of fluid inclusions were recognized in the samples studied: 1) type-I, aqueous, vapour + liquid inclusions (Fig. 3A), 2) type-II, aqueous + carbonic (mainly CO_2) inclusions, with the aqueous phase being in liquid and the carbonic being composed of either one or two phases at room temperature (Fig. 3B), and 3) type-III, carbonic (mainly CO_2) inclusions without visible aqueous phase. Opaque daughter minerals were observed in some type-II inclusions (Fig. 3C).

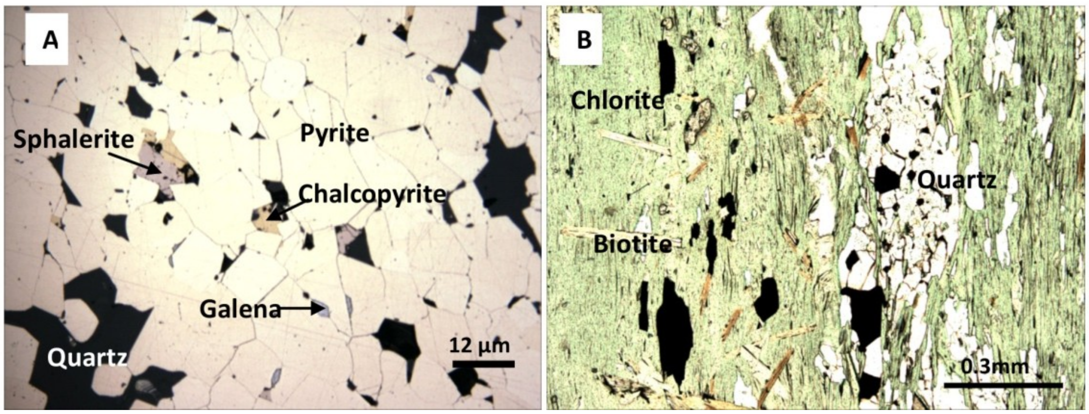

Figure 2. A) Photomicrograph of sulphide ore minerals and associated quartz in primary massive ore; reflected light; B) Photomicrograph of sulphide minerals and quartz veinlets that have been stretched parallel to schistosity; transmitted plane polarized light.

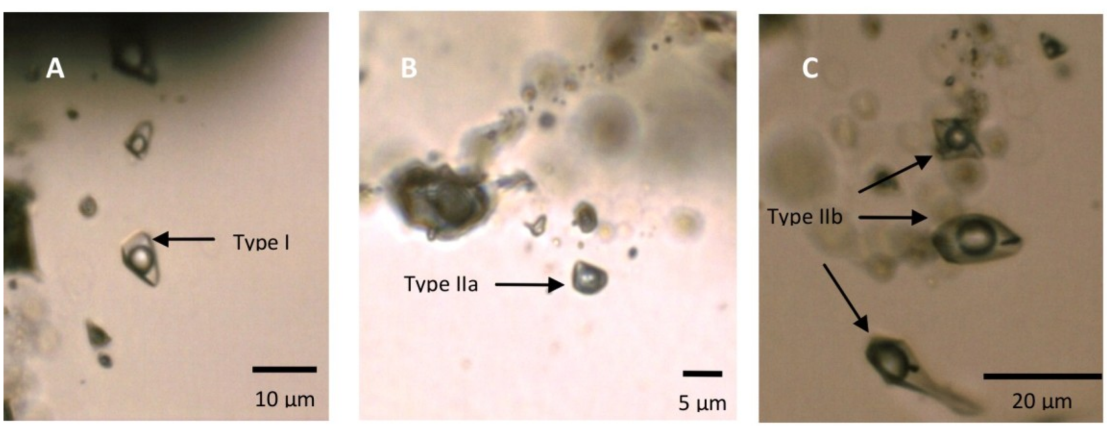

Figure 3. A) Type-I, aqueous fluid inclusions in quartz associated with primary ore; B) Type-IIa, aqueo-carbonic inclusions in quartz associated with secondary ore; C) Type-IIb, secondary aqueo-carbonic inclusion with opaque daughter mineral in quartz associated with primary ore. All in transmitted plane polarized light.

Fluid inclusions in primary ores are mainly aqueous (Type I), with homogenization temperature (T_h) from 150°C to 275°C and salinities from 6 to18%$_{wt}$ NaCl equiv. (Fig. 4A). Secondary aqueous fluid inclusions display similar salinities and an overall higher T_h (79°C - 340°C), whereas secondary CO_2-rich inclusions (Types IIa and IIb) have lower salinity (5 - 11%$_{wt}$ NaCl equiv.) and higher T_h (394°C - 396°C) (Fig. 4A). Fluid pressures estimated from secondary carbonic fluid inclusions range from 500 to 1500 bars.

The fluid inclusions in secondary ores have variable T_h from 86°C to 305°C for aqueous primary inclusions, and from 103°C to 400°C for secondary aqueous inclusions (Fig. 4B). Primary and secondary aqueo-carbonic inclusions have higher T_h values than the aqueous type, ranging from 200°C to 375°C, and from 250°C to 400°C, respectively (Fig. 4B). Salinity is moderate for primary aqueous fluid inclusions (4-13 $\%_{wt}$ NaCl equiv.), and extremely variable for secondary aqueous inclusions. The salinities of aqueo-carbonic inclusions range from 4 to 8$\%_{wt}$ NaCl equiv. for primary inclusions, and 6 to 14$\%_{wt}$ NaCl equiv. for secondary inclusions (Fig. 4B). Fluid pressures calculated from the CO_2-bearing inclusions range from 500 to 3500 bars.

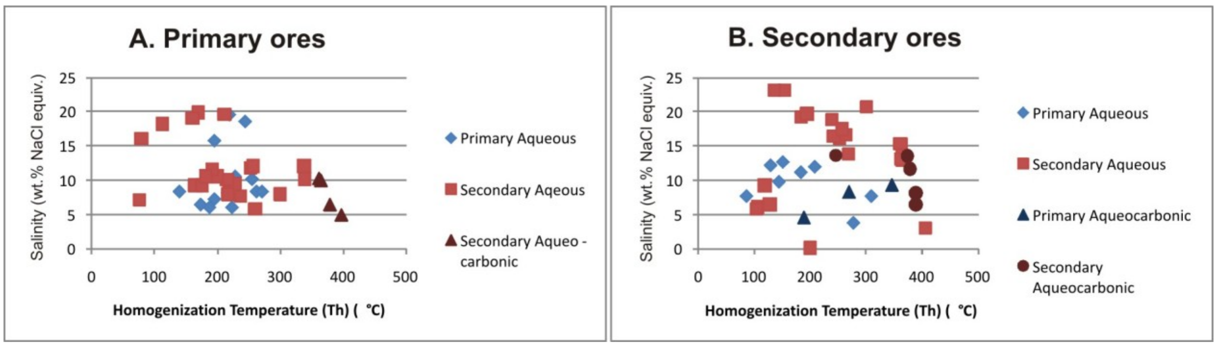

Figure 4. Salinity-homogenization temperature correlation diagrams for fluid inclusions in primary (A) and secondary ore (B).

Discussion and Conclusions

The fluid inclusion data suggest that the fluids responsible for primary mineralization are dominantly of aqueous type, with relatively low temperatures and salinities. These characteristics are compatible with modified seawater and are typical of most VMS mineralization. The CO_2-bearing inclusions in the primary mineralization are interpreted to be secondary, although some of them look like they could be primary. Fluid inclusions in the secondary ores, characterized by an abundance of CO_2-bearing inclusions, are typical of mineral deposits formed in metamorphic terranes (e.g., orogenic type gold deposits), and the fluid pressures calculated are compatible with conditions from peak metamorphism to retrograde metamorphism.

CO_2-rich inclusions have been found in many other VMS deposits in the world. Some of them were interpreted to represent fluids circulating after primary mineralization, and others were considered to represent fluids responsible for primary mineralization. Based on the observation that most orogenic-type gold deposits were formed from CO_2-rich fluids and the interpretation that the CO_2-rich inclusions in the primary ores are of secondary origin, we tentatively propose that remobilization of the primary ore by CO_2-rich fluids during regional metamorphism is at least partly responsible for the enrichment of gold in the Rambler VMS deposits. The CO_2-rich fluids may have been derived from Devonian retrograde metamorphic fluids (Hibbard, 1983; Anderson et al, 2001) If these fluids introduced gold into the VMS deposits, they may have also formed separate gold deposits in the region, such as the Nugget Pond and Stonger Tight deposits (Anderson et al., 2001; Skulski et al., 2009). Whether or not there was gold enrichment during primary VMS mineralization needs to be further verified.

Acknowledgements

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