Distribution, Form, and Origin of Precious Metals in the Boomerang and Domino Volcanogenic Massive Sulfide Deposits, Tulks Belt, central Newfoundland

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ABSTRACT

The Boomerang and Domino argentiferous volcanogenic massive sulfide deposits are hosted with felsic pyroclastic rocks of the Tulks Belt, Victorica Lake Supergroup, central Newfoundland. The Boomerang deposits' indicated mineral resources were recently calculated to be 1.36 million tonnes grading 7.09% Zn, 3.00% Pb, 0.51% Cu, 110.4 g/t Ag, and 1.66 g/t Au at a 1% Zn cut-off grade with similar grades inferred for the nearby Domino deposit and other deposits within the belt (e.g., Tulks Hill, Tulks East, Bobby's Pond, Jack's Pond, and Curve Pond). The ore constituents from the Boomerang and Domino VMS deposits consists of pyrite, sphalerite, galena, chalcopyrite, and tetrahedrite with accessory arsenopyrite. Massive sulfide ore range from nearly massive units to laminated fine-grained sphalerite and galena in association with pyrite ± irregular-shaped chalcopyrite forming pressure shadows, up to 5 cm in size. Porphyroblastic pyrite and arsenopyrite are attributed to greenschist-grade metamorphism with upper temperature estimates of 380±14°C, based on arsenopyrite geothermometry.

Multi-element ICP-MS analysis of precious metals-enriched massive sulfides (n=156) of the Boomerang deposit show positive correlations (>95% confidence level) between Au and Ag with As, Cu, Hg, Pb, Sb, Cd, and Zn; Au and Ag are strongly correlated (r`=0.86). Gold is associated with arsenian phases and Ag with tetrahedrite- and galena-rich assemblages. EPMA reveals Ag as a solid solution compnent within tetrahedrite, with minimal Ag within galena. Tetrahedrite in the Boomerang and Domino VMS deposits exhibit an average Fe/(Fe+Zn) and As/(As+Sb) ratios of 0.62±0.09 and 0.047±0.033, respectively, assocaited with an average 7.20 Ag wt.%. Silver substitution in tetrahedrite decreases with increasing Cu concentration, which is reflected in the Cu-Ag negative correlation (r`=-0.95). Furthermore, the relationship between Ag and Sb (r`=0.34) in tetrahedrite is such that increased Sb concentration is believed to permit the solid solution to incorporate more Ag. Sphalerite has a range of 5.4 to 12.8 mole % FeS.

Laser ablation ICP-MS results from selected samples (n=8) of arsenopyrite and pyrite grains show elemental abundance variations from core to rim, complimenting earlier EPMA results. Arsenopyrite rims are enriched in precious metals, averaging 228 ppm Au and 25 ppm Ag with Co richer cores. Precious metal enrichment is evident in the cores of pyrite porphyroclasts, averaging 13 ppm Au and 382 ppm Ag with Co, Ni, and Hg concentrated in the rims. Au-Ag mobilization is evident during dynamic deformation, consistent with formation of late orogenic A-Sb-Ag deposits in the belt.

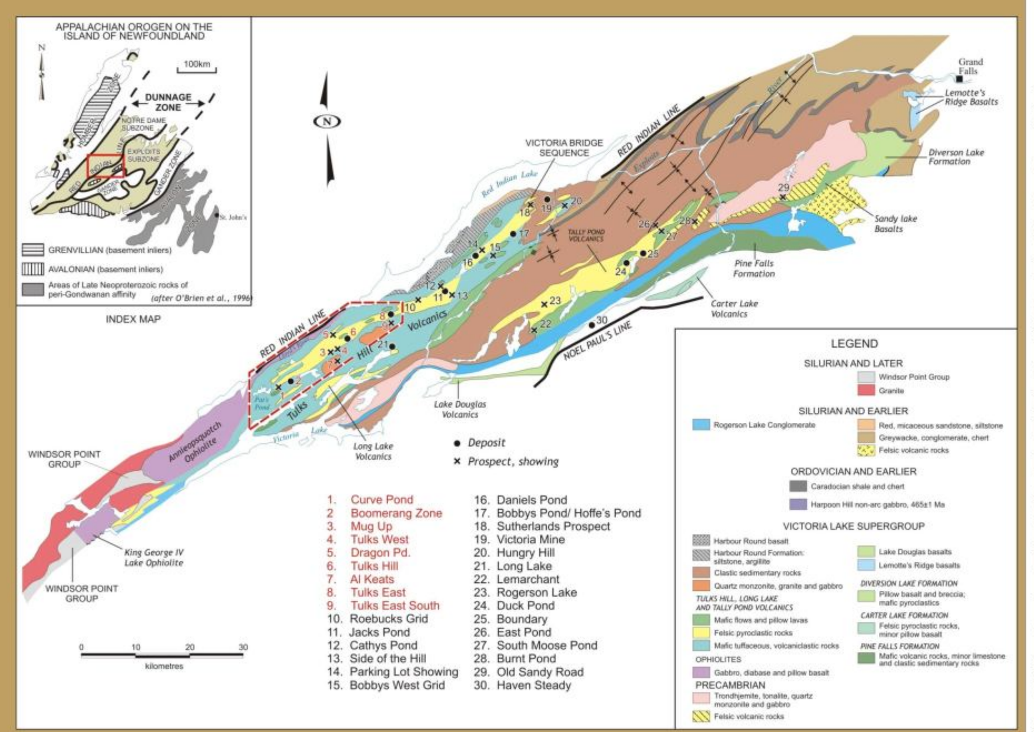


Figure 1. Geological map of the Victoria Lake Supergroup showing the location of the Tulks Hill Volcanic Belt and selected VMS deposit locations. (Modified after Evans & Kean, 2002; Hinchey, 2007).

STRATIGRAPHY

Because of major faulting and thrusting associated with the Tulks Volcanic Sequence it is difficult to determine the original stratigraphy which hosts the Boomerang massive sulfide deposit. Drill holes GA-04-11, GA-05-12, and GA-05-15 (Fig. 3)are believed to show the most complete package with the least impact of associated thrusting (G.Squires, per comm.), however; more studies are needed in this are to determine the extent of structural complications. Considering the three drill holes previously mentioned, the basic stratigraphy from bottom to top begins with the footwall sericitic tuffs, which are overlain by the Boomerang massive sulfide lens. Typically just above the massive sulfide lens there is an exhalative horizon which is composed of graphitic sediments and black argillites with associated pyritic muds. In contact with the exhalative horizon there are the hanging wall tuffs which have intermixed siltstone and grey and black argillite beds in close proximity to the exhalative horizon. This unit is then intruded by mafic sills which contain intermixed units of hanging wall tuffs. Above the mafic sills are intermixed sandy ash and lapilli tuffs which are capped by mafic to intermediate flows on the northwestern extremity of the section.

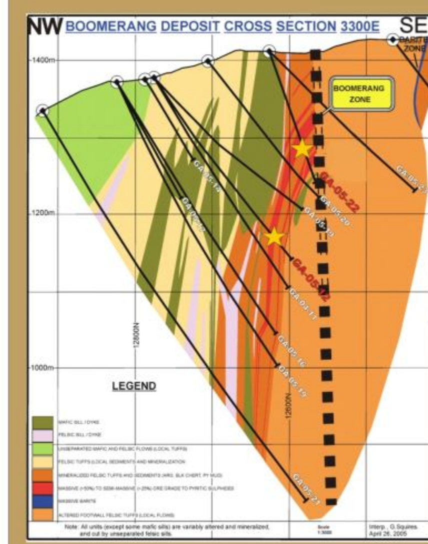


Figure 2. Geological Cross section of the Boomerang VMS deposit interpreted by Gerry Squires (2005) from Messina Minerals Inc. website.

Figure 3.a. Photograph of polished slab consisting of fine-grained brown sphalerite and silvery grey galena interbedded with fine- to medium-grained pyrite with pyrite porphyroblasts hosted in silica +/- carbonate gangue. Sample 0512-258.75.Note: Labeling stands for DDH (0539) sampled at a depth of 306.05m.

Figure 3.b. Photograph of polished slab consisting of fine-grained pyrite and siliceous and chloritic gangue, laminated fine-grained brown sphalerite and galena occurs interlayered with minor fine-grained chalcopyrite, grading into thicker layers of galena and sphalerite (with minor galena) and pyrite porphyroclasts up to 1cm in size, hosted in chlorite as observed in the centre of the photo. Grain size increases towards the right with varying amounts of sphalerite, galena, pyrite, and lesser amounts of chalcopyrite. Geochemical assays indicate this sample (0539-306.05) is silver rich.

Figure 3.c. Photograph of polished slab (quartered core) consisting of laminated fine-grained grey brown sphalerite, recrystallized pyrite, and trace chalcopyrite with 1mm pyrite porphyroblasts hosted in siliceous gangue. Sample 0522-115.6: approximately 21cm in length.

Figure 3.d. Photograph of polished slab consisting of large clusters of coarse-grained arsenopyrite and pyrite porphyroblasts in very fine-grained quartz groundmass. Arsenopyrite grains are as large as 5mm and angular to sub-rounded in nature. Sample 0541-277.4: 13cm long.

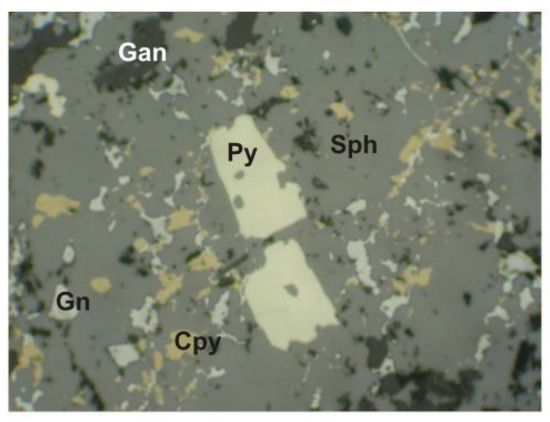


Figure 4a. Reflected plane polarized light (PPL) photomicrograph of nearly massive sphalerite (sph) (dark purplish grey) with minor galena (gn) (silvery grey) and chalcopyrite (cpy) (brassy yellow) and euhedral pyrite (py) porphyroblasts (creamy yellow). Sample 06107-524.7: FOV = 3.2mm.

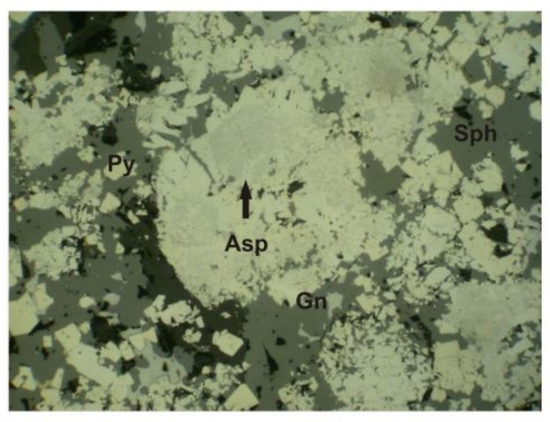


Figure 4b. Reflected plane polarized light photomicrograph showing areas of arsenopyrite replacing and overgrowing galena and areas of fine-grained pyrite within the greater arsenopyrite porphyroclast surrounded by sphalerite, galena, and fine-grained quartz-carbonate gangue. Sample 0543-297.75A: FOV = 3.2mm.

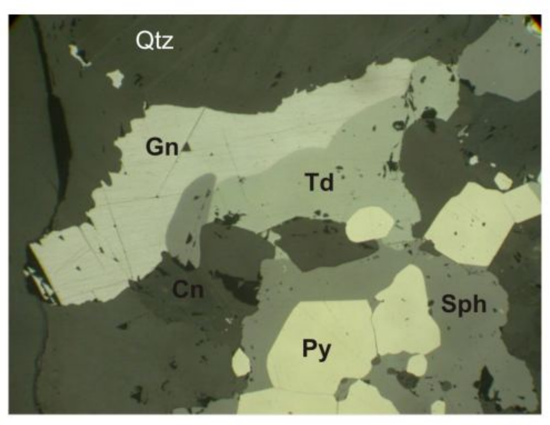


Figure 4c. Reflected plane polarized light (PPL) photomicrograph of anhedral galena (gn) (silvery grey) and tetrahedrite (td) (grey-green), with sphalerite (sph) (medium purplish grey) and subhedral pyrite (py)porphyroblasts (up to 1mm), enclosed within celsian - barium aluminum silicate (cn) (dark grey) and siliceous (qtz) gangue (black). Sample 06119-631.02: FOV = 3.2mm.

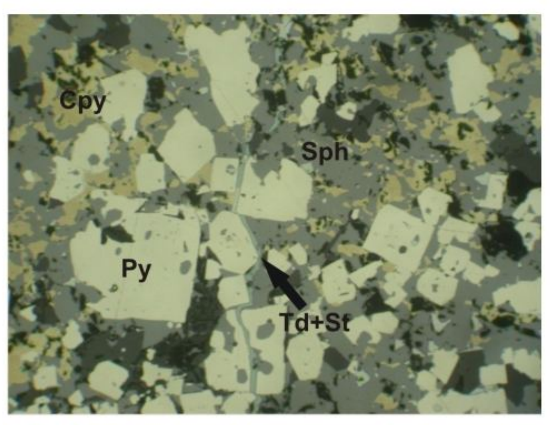


Figure 4d. Reflected plane polarized light (PPL) photomicrograph of pyrite (py)porphyroblasts (up to 1.0mm in size) enclosed within interstitial sphalerite (sph) and chalcopyrite (cpy) cut by a microveinlet (0.125 mm wide) of fahlore (td) (tetrahedrite-tennantite), and silver-bearing mineral Stephanite (st) (centre) filling irregular fracture, sub vertically oriented in the photomicrograph. The dilational fracture locally follows grain boundaries of pyrite porphyroblasts. Sample 06107-524.7: FOV = 3.2mm.

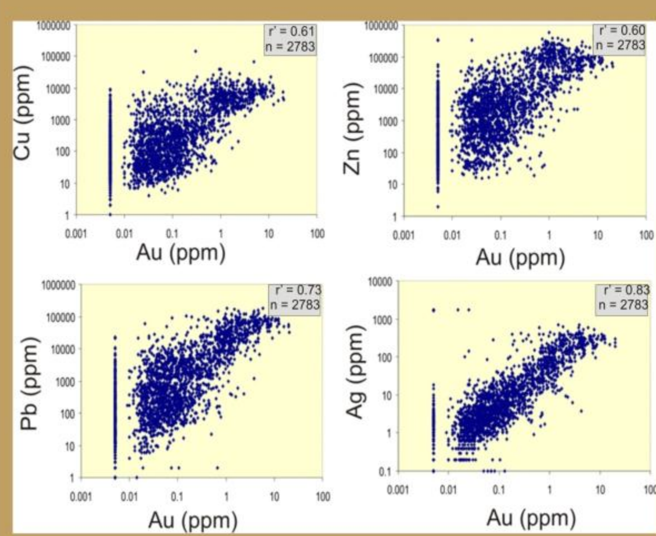


Figure 5a. Bivariant plots of base metals (Cu, Pb, Zn, and Ag) versus Au from bulk assay data of the Boomerang deposit. Gold

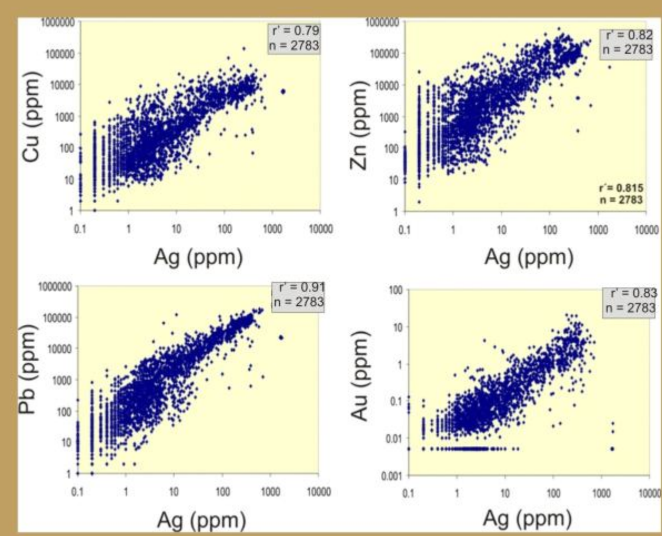


Figure 5b. Bivariant plots of base metals (Cu, Pb, Zn, and Au) versus Ag from bulk assay data of the Boomerang deposit. The

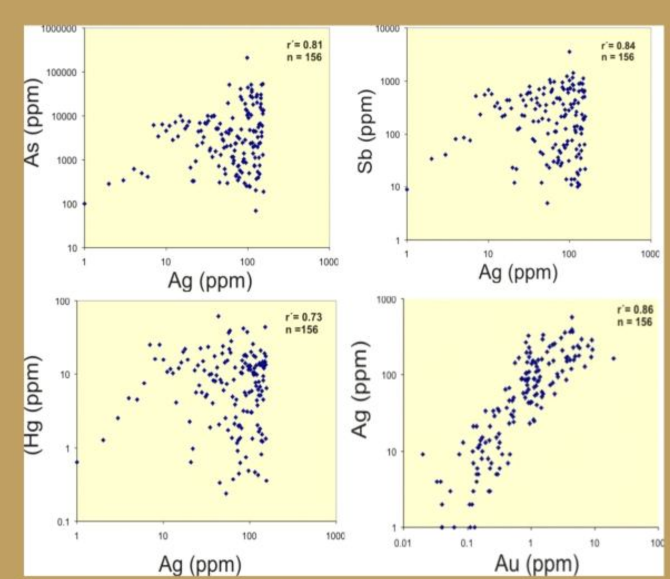


Figure 5c. Bivariant plots of selected elements (Hg, As, Sb) versus Ag and Ag versus Au from the bulk assay data of the domino deposit. The detection limit for Ag is 0.1 ppm. Bulk assay from the

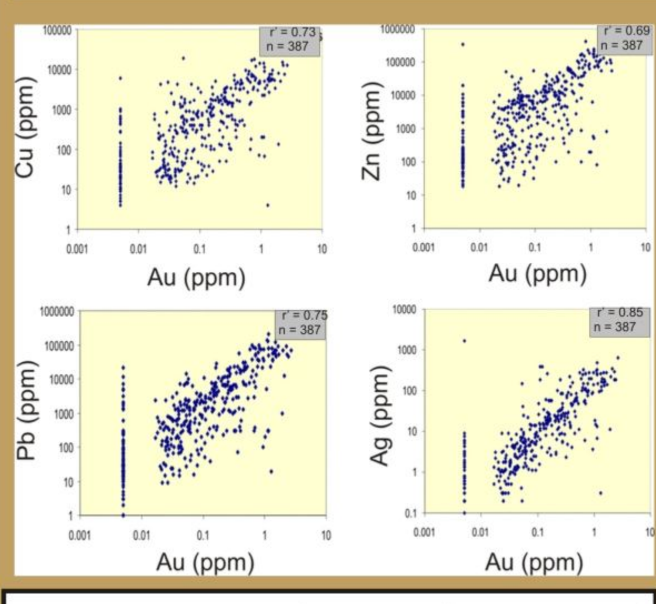


Figure 5d. Bivariant plots of base metals (Cu, Pb, Zn, and Ag) versus Au from bulk assay data of the Domino deposit. Gold

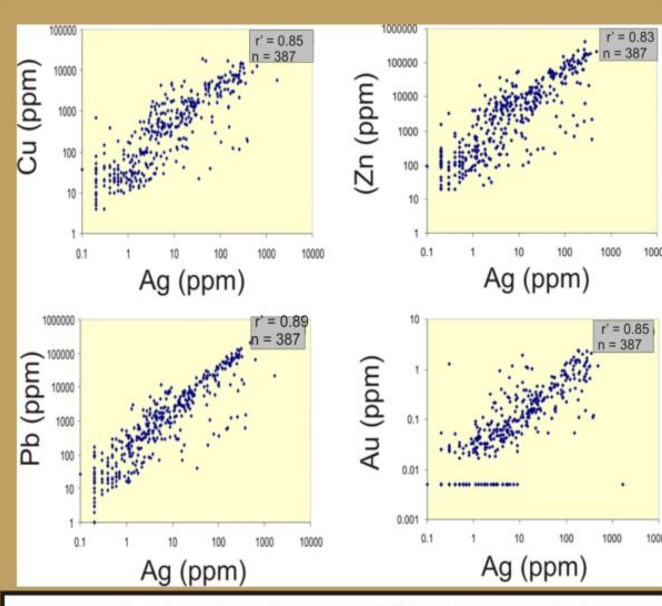


Figure 5e. Bivariant plots of base metals (Cu, Pb, Zn, and Au) versus Ag from bulk assay data of the Domino deposit. The detection limit

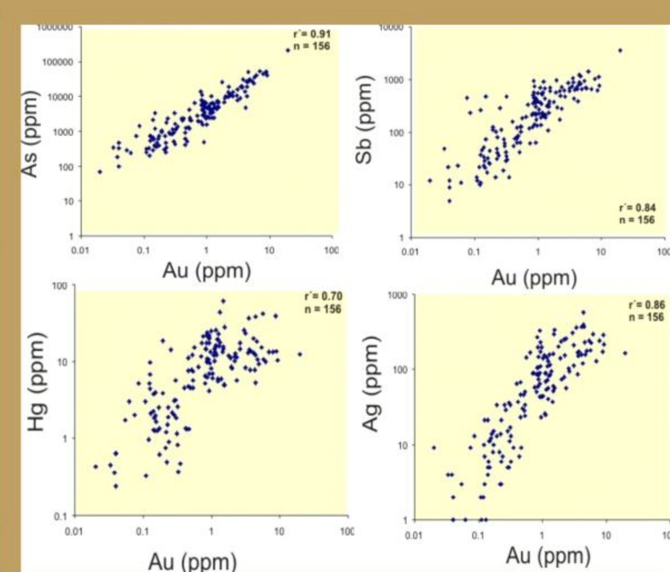
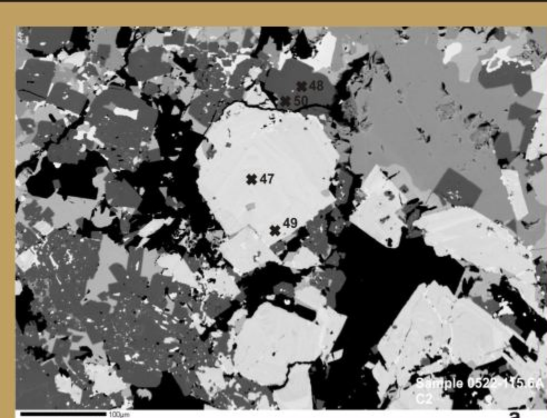
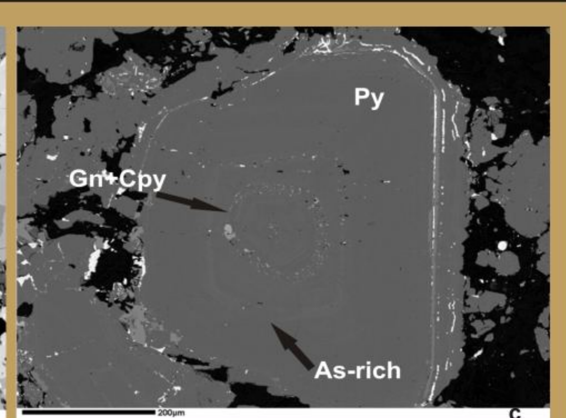


Figure 5f. Bivariant plots of selected elements (Hg, As, Ag, Sb) versus Au from the bulk assay data of the domino deposit. The detection limit for Au is 0.005 ppm. Bulk assay from the assessment file on drilling





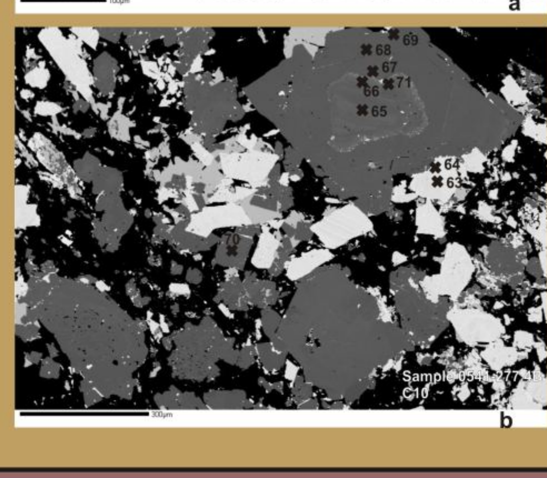


Figure 6 a-b. LA-ICP-MS analysis points of selected representative pyrite and arsenopyrite cores from the Boomerang massive sulfide deposit. Arsenopyrite shows up as light grey and pyrite shows up as dark grey.

Figure 6 c. SEM-BSE image of a representative sample from the Boomerang massive sulfide deposit showing compositional zoning and inclusion trains of galena and chalcopyrite within a pyrite porphyroclast.

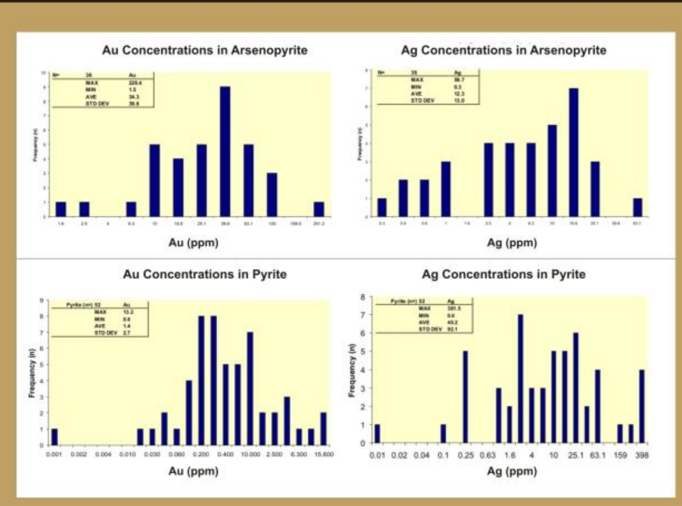


Figure 7. Concentration levels of Au and Ag in arsenopyrite and pyrite grains from LA-ICP-MS analysis using an in-house 266nm Nd:YAG laser system attached to a VG Fisions PlasmaQuad II+"S" quadrupole mass spectrometer.

DISCUSSION

The Midas Pond gold prospect lies in the same southwestern portion of the Tulks Belt volcanic sequence as the Boomerang and Domino VMS deposits, in altered and sheared felsic and mafic volcanic and volcaniclastic rocks (Evans and Wilton, 2000). In the case of the Midas Pond Gold prospect, gold is spatially related to pyrite occurring in three structurally controlled vein sets with noted values of 7.3 g/t Au over 0.9 m and 14.7 g/t over 1.15 m. The Midas Pond Au prospect occurs within a 200 m wide, regional northeast-trending, steeply northwest dipping shear zone grading into less deformed felsic and mafic volcanic rocks that locally host massive sulfides. Gold mineralization believed to have formed from auriferous hydrothermal fluids infiltrating the host rocks through the shear zone and shearing is interpreted to form during late D1, regional deformation and further deformed by D2 deformation, described as a flexural event, seen as kinking in host rocks (Evan and Wilton, 2000).

The nearly massive pyrite and arsenopyrite-silica-rich unit (sample 0541-277.4) in the Boomerang VMS deposit may be related to the genesis of mineralization analogous to Midas Pond Gold Prospect, i.e., epigenetic in nature, forming from infiltrating hydrothermal fluids rich in Au, Ag, As, ± Cu, Zn, Pb, Sb, Hg, Se, Te, Sn, Mo, Bi passing through sheared or brecciated zones of high fluid flow. The Boomerang and Domino deposits are said to be displaced 200 m horizontally and 100 m vertically, and pronounced high angle, sub-vertical faulting in the region is abundant, consist with the mineralization in the Midas Pond Gold Prospect.

EPMA data indicate slight rim to core enrichment of As, varying from an average 43.0 (wt. %) found in rims to an average 43.5 (wt. %) found in the cores of arsenopyrite. Reversely, an increase in As concentrations from core to rim, varying from an average 0.29 (wt. %) found in cores to an average of 0.34 (wt.%) found in rims of pyrite; both coinciding with Au abundance data from LA-ICP-MS, where Au concentrations were highest in rims of arsenopyrite and cores of pyrite. Pyrite is well known as having the tendency of incorporating significant amounts of elements and inclusions evident in pyrite from the Boomerang and Domino deposits.

Silver sulfides only occur under low temperature/high pH conditions not common in hydrothermal fluids giving rise to massive sulfides (Zn, Cu, As, Pb, Fe), explaining the limited stephanite found (sample 06107-524.7) in late dilatational fractures within the massive sulfides of the Domino deposit, indicating a secondary - lower temperature, higher pH hydrothermal fluids peculating later post massive sulfide deposition.

ACKNOWLEDGMENTS

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