Multiple Sulfur Isotope Geochemistry of Au-rich systems of the southern Abitibi subprovince, Québec, Canada

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The ~2.7 Ga Doyon-Bousquet-LaRonde (DBL) mining camp (175 Mt of ore, 28Moz Au), Abitibi subprovince, comprises three of the largest Au-rich volcanogenic massive sulfide (VMS) deposits in the world, in addition to several intrusion-related and shear-zone hosted Au-rich vein deposits. A magmatic contribution is inferred in these systems based on the presence of major metamorphosed advanced argillic alteration style assemblages, a Au-Cu association and telescoped intrusion-related and seafloor systems. In this study we utilized multiple sulfur isotope analysis to determine the sulfur sources within the different ore deposits of the DBL mining camp, and compared these results with those from VMS deposits of the Noranda Camp, orogenic gold veins of the Val-d’Or district and from the world-class Canadian Malartic intrusion-related gold deposit.

Sulfides from the Au-rich VMS deposits of the DBL mining camp have $\delta^{34}$S$_{V-CDT}$ values of +0.8 to +3.5‰ and $\Delta^{33}$S$_{V-CDT}$ values of -0.16 to -0.01‰. A single exception of sphalerite with minor pyrite from the LaRonde-Penna Zone 7 has a $\Delta^{33}$S value of -0.29‰. Sulfides from Au-rich intrusion-related and shear-hosted vein deposits have slightly heavier $\delta^{34}$S values of +1.7 to +5.1‰, but $\Delta^{33}$S values also near zero (-0.14 to +0.00‰). We interpret the near-zero $\Delta^{33}$S values for these deposits to indicate a primary magmatic affinity, in which the sulfur was either leached from sulfide in the volcanic pile, or was directly precipitated from magmatic volatiles. In contrast, the slightly more negative $\Delta^{33}$S value of the LaRonde Penna Zone 7 sample likely reflects a minor contribution (~10%) to the ore-forming system of sulfur ultimately sourced as seawater sulfate.

The orogenic gold veins of the Val-d’Or district have ranges of $\delta^{34}$S$_{V-CDT}$ and $\Delta^{33}$S$_{V-CDT}$ values (+0.25 to +5.86‰, and -0.07 to -0.00‰, respectively) similarly indicating a dominantly magmatic sulfur source, whereas the lower $\Delta^{33}$S values indicate a very minor contribution of Archean seawater sulfate. The sulfur isotope characteristics of the Val-d’Or deposits and the VMS ore sulfides of the DBL mining camp contrast with VMS deposits of the Noranda Camp that have $\delta^{34}$S values of -1.90 to +2.49‰ and $\Delta^{33}$S values of -0.03 to -0.59‰ indicate a seawater sulfate origin for up to 25% of the sulfur in ore sulfides. Notably samples from the oxidized intrusion-associated Canadian Malartic gold deposit has large range of $\delta^{34}$S values (-3.45 to +4.30‰) and dominantly positive $\Delta^{33}$S values (-0.03 to +0.12‰), which implies a different source of sulfur for this deposit likely from sulfur originating in the surrounding metasediments of the Pontiac Group.
Based on $\delta^{34}$S values alone, these ore-forming environments would conventionally be interpreted as having a greater contribution from surficial sulfur. However, the $\Delta^{33}$S values indicate that the Au-rich deposits of the southern Abitibi must have been formed in a dominantly magmatic environment. Such specificity highlights the utility of multiple sulfur isotope analysis for interpretation of complex ore-forming environments, including systems that have undergone relatively high levels of metamorphism.