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Determining hydrothermal fluid source for gold deposits through geochemistry of monazite and xenotime crystals

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Two major types of gold-bearing deposits that are envisioned to form within accretionary metamorphic terranes include orogenic gold deposits created by metamorphic fluids and gold-rich porphyry deposits formed by magmatic-hydrothermal fluids. Unfortunately, no conclusive geochemical method for differentiating between the two fluid types has been offered.

Rare earth element-bearing phosphate phases such as monazite and xenotime are alteration products found in both orogenic and intrusion-related deposits. These phases have recently proven important for U-Th-Pb geochronological investigations of ore formation because they are not subject to low- to moderate-temperature resetting such as is common with silicate phases dated by the $^{40}Ar/^{39}Ar$ method. In addition, their chemistry can be used to differentiate between magmatic, metamorphic, diagenetic, and hydrothermal formation [1,2,3]. We found differences in the chemistry of phosphates formed from magmatic-hydrothermal fluids versus metamorphic-hydrothermal fluids that can, in turn be used to differentiate between gold deposit types.

In-situ chemical characterization of monazite and xenotime from orogenic and gold-bearing porphyry deposits was performed using an electron microprobe. Hydrothermal monazite and xenotime from orogenic veins in the granite-hosted Empire deposit (Grass Valley district), the greenschist-hosted Sixteen to One deposit (Alleghany district), and the greenschist-hosted Harvard deposit (Mother Lode belt) from California were analyzed. Hydrothermal phosphates from the potassic alteration zones of the Butte, Montana and Pebble, Alaska gold-bearing porphyry deposits, unequivocal examples of magmatic-hydrothermal deposits, were chosen for comparison.

Distinct geochemical differences are observed in samples from the two deposit types. Magmatic-hydrothermal monazites have no Ce but have slight to moderate negative Eu anomalies, whereas orogenic-hydrothermal monazites have consistent slightly negative Ce anomalies and no to slightly positive Eu anomalies. Magmatic-hydrothermal xenotime consistently have higher Th and Th/U than orogenic xenotime, and the monazite consistently contains higher Th and Th/U than granite-hosted orogenic monazite but overlap with values from volcanic rock-hosted orogenic monazite. Additional distinguishing geochemical features include Ce/Pr, Gd/Tb, Eu/Tb, Lu/Dy, and Gd/Eu ratios.

Our study suggests that phosphate chemistry can be used to distinguish orogenic from porphyry deposit types. The next step is to apply this technique to deposits within gold provinces found from Canada to Russia to determine if certain controversially classified deposits, such as Pogo, Alaska are intrusion-related or orogenic systems. Both orogenic gold and reduced intrusion-related gold deposits are hypothesized to form at similar mesozonal depths with similar mineralogy and geochemical signatures, which has previously made them difficult to differentiate between. A possible distinguishing factor may be differences in REE and trace element chemistry of the phosphates related to hydrothermal alteration. Determining which gold deposit type exists in a region is critical to exploration and will indicate if mineral assessments should focus on structures or plutons, which will have profound implications for future exploration in these terranes.

References:

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