LA-ICPMS measurements of gold abundance in sulphide and rock-forming minerals from granitoids, southwestern New Brunswick, Canada: insights into the genesis of intrusion-related gold systems

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The abundances of gold and selected trace elements in magmatic sulphide and rock-forming minerals from Silurian-Devonian granitoids in southwestern New Brunswick, a part of Canadian Appalachians, were quantitatively analyzed by laser-ablation inductively-coupled-plasma mass-spectrometry (LA-ICPMS). Major elements in these minerals were analyzed by electron microprobe. Gold is mainly hosted in sulphide minerals (i.e., chalcopyrite, pyrrhotite, and pyrite) as sub-micron inclusions (nano-nuggets). Gold in major rock-forming minerals (i.e., plagioclase, K-feldspar, biotite, hornblende, muscovite) and oxides (i.e., magnetite, ilmenite) are undetectable (< 0.02 ppm). Gold distribution coefficients between sulphide minerals and granitoid melt are empirically established as:

$$D_{Au}^{cpy/melt} = 948 \pm 269,\ D_{Au}^{po/melt} = 150 \pm 83,$$

$$\text{and } D_{Au}^{py/melt} = 362 \pm 96.$$

This result suggests that the behaviour of gold in these magmatic rocks was controlled by the conditions of sulphur saturation during magmatic evolution; the threshold of physiochemical conditions for sulphur saturation in the melts is a key factor affecting gold activity in the systems. Gold behaves as an incompatible element prior to the formation of any immiscible sulphide liquid that recrystallized sulphide minerals, but it becomes compatible upon sulphide saturation in the melt. Gold would be enriched in sulphur-undersaturated granitoid magmas with fractionation, favouring the formation of intrusion-related gold deposits from late-stage gold-rich fluids (i.e., through partitioning processes). On the other hand, gold becomes depleted in residual felsic melts if they have become sulphur-saturated through differentiation, resulting in the early phases of a granitoid suite having the higher gold concentration. However, Cl-bearing magmatic hydrothermal fluids with low pH have the potential to selectively scavenge gold incorporated into early sulphide minerals formed within an evolving magma, especially with increasing oxidation state of the exsolved fluids. Late stage fluids, derived from either progressively cooling magmas (volatile saturated) at depth or convective circulation of meteoric water buffered by reduced carbon-bearing sediments, may also scavenge gold from early sulphide minerals. If a significant amount of gold produced in this manner is concentrated in a suitable geological environment, such as shear zones and (or) hydrofracture systems, intrusion-related gold deposits may also be generated (i.e., by leaching processes). Exploration for intrusion-related gold systems should focus on the areas around evolved phases of granitoid suites that did not achieve early sulphur saturation. For a sulphur-saturated granitoid suite, however, less differentiated phase and associated structures may be the other target for gold exploration.

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