Gold Biomineralisation Insights Offer Implications for Exploration and Extraction

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The role of micro-organisms as the main drivers of metal mobility and mineral formation under Earth surface conditions is now widely accepted. However, it is commonly believed the formation of secondary gold (Au) in surface environments is attributed to abiotic processes, which are mediated by non-living chemical and physical factors in the environment.

Research by a group of experts including IMER researchers Dr Frank Reith and Professor Joel Brugger, has found direct evidence that bacteria are actively involved in the biogeochemical cycling of rare and precious metals. The research has opened the way for the development of bioexploration and bioprocessing tools which could revolutionise the exploration for gold, improve gold extraction and assist hydrometallurgical processes.

Microorganisms are paramount for metal cycling and mineral formation. Some metal ions are essential for microbial nutrition, while others are oxidised or reduced to obtain metabolic energy. In particular, heavy metal ions cause toxic effects to microbiota. Hence micro-organisms have developed genetic and proteomic responses to regulate metal homeostasis.

In contrast to most other metals, gold is rare, inert, non-essential and does not form free ions in aqueous solution under surface conditions. This study looked at the impact of microbial processes on Au mobility, tracing the effect of indigenous bacterial such as C. metallidurans on Au complexes. It addressed four questions: is the reduction of Au(III) by C. metallidurans an active, energy-dependent process; how is Au distributed and speciated in cells; which form is present in biofilms and Au grains; and finally, what are the genetic and biochemical responses to the presence of Au complexes in C. metallidurans. Kinetic experiments with metabolically active cells confirmed a two-stage reduction for Au(III) complexes, finding several mechanisms may be used by C. metallidurans to detoxify Au (III)-complexes. Research found C. metallidurans, which forms biofilms on Au grains, rapidly accumulates Au(III)-complexes from solution. Bulk and microbeam synchrotron x-ray analysis revealed that cellular Au accumulation is coupled to the formation of Au(I)-S complexes. This process promotes Au toxicity and the C. metallidurans reacts by inducing oxidative stress and metal resistant gene clusters to promote cellular defense. As a result, Au detoxification is mediated by a combination of efflux, reduction and possibly methylation of Au-complexes leading to the formation of Au(I)-Ccompounds and nanoparticulate Au(0). The study concluded other precious metals such as Platinum Group Elements (PGE) share geochemical properties with Au. Similar to Au, zones of secondary PGE enrichment occur in surface environments and were attributed to their solubilisation, transport and precipitation.
The discovery of active microbially driven biomineralisation may lead to the development of applications such as the development of Au-specific biosensor technology enabling in situ Au measurements.