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Fungal-gold biogeochemistry and its applications for gold recovery from tailings

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Relative to other metals, gold biogeochemistry is understudied and has primarily focused on bacterial reduction or detoxification of soluble auric/aurous complexes that form elemental gold nanoparticles. In 2019, fungi were experimentally found to be capable of oxidizing elemental gold using metabolites such as carbonyl-rich ligands and superoxide (O_2^-), highlighting an important fungal contribution to gold redox cycling and mobility within metal-rich environments. Placer gold grains are ideal natural materials that can be analyzed to complement experimental studies to deepen our understanding of gold biogeochemical cycling influenced by fungi. For this present study, ca. 300 gold grains were collected from historic, artisanal placer deposits in Australia, New Zealand, and Finland. High-resolution scanning electron microscopy analysis of the gold grains revealed fungi-like structures occurring within crevices. Crevices (i.e., topographically low regions) on gold grain surfaces were previously recognized as “hotspots” for the accumulation of organics and clays and, thus, microbially induced gold biogeochemical cycling. High-throughput DNA profiling confirmed the presence of fungi on gold grains from all locations but also identified *Ascomycota* as the predominant phylum. Although most detected fungi were not previously known to be involved in gold redox cycling, metabolic DNA array assays showed that these fungi possessed functional capacities to produce carbonyl-rich ligands (e.g., oxalate) and superoxide for gold dissolution as well as metal detoxification. The multi-analytical approach involving electron microscopy, high-throughput DNA sequencing, and functional gene assays offers an integrative framework for resolving fungal influences on metal cycling directly at the mineral–microbe interface. These results indicate that fungi are metabolically capable of directly influencing gold dissolution and reprecipitation processes at grain surfaces. Although increased gold purity observed on placer grains has been attributed to bacterial activity, our findings suggest that fungi are also potential contributors to in-situ gold redox cycling. Harnessing their metabolic capabilities offers promising applications for bioremediation and targeted metal recovery from tailings. This provides a pathway for designing biological alternatives to toxic cyanide-based extraction methods for sustainable resource recovery. Such insights are crucial for supporting resource resilience and environmental sustainability.