

## **An approach to carbon-negative in situ mining of platinum group elements from ultramafic-hosted ore**

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The platinum group elements (PGE) bearing J-M Reef, hosted in Montana's ultramafic Stillwater Complex, is the location of a conventional subsurface mining and surface ore processing facilities. An alternative approach to this energy-intensive mining operation is carbon-negative in situ mining technology which envisions creating a highly permeable subsurface ore body with electro-hydraulic fracturing followed by injection/circulation of CO<sub>2</sub>-charged lixiviant mobilizing PGE and permanently trapping carbon as secondary carbonates followed by the recovery of PGE rich pregnant lixiviant for surface processing.

In-situ mining with CO<sub>2</sub> mineralization involves three competing chemical reactions: i) acid consuming CO<sub>2</sub> mineralization reactions, ii) acid producing and oxidant consuming sulfide leaching reactions, and iii) metal solubilizing reactions enhanced by complexing lixiviants. Based on literature review of leaching and geochemical modeling, four lixiviants were selected for screening tests to identify a suitable lixiviant for PGE mobilization. The candidate lixiviants are based on ammonia, thiosulfate, thiocyanate, and thiourea. Preliminary tests used pH 4.5 buffered lixiviants in a sodium acetate background solution with no added CO<sub>2</sub>. Both air-oxygen saturated and hydrogen peroxide-spiked lixiviants were reacted with sulfide concentrate from Stillwater mine for 1 to 18 days.

The sodium acetate control and NH<sub>4</sub>Cl lixiviants exhibited similar behavior with 2.0±0.2 and 2.9±0.7 times more sulfides oxidized, and nickel released in peroxide test compared to the no peroxide test. However, neither palladium nor platinum were detected. The thiocyanate and thiourea lixiviants exhibited similar nickel leaching behavior to the non thio-lixiviants for the first 4 days (no peroxide) and 8 days (peroxide) of the test. The leaching behavior of the thiosulfate lixiviant resulted in lowest (no peroxide) and highest (peroxide) nickel concentrations during leaching. All the thio-lixiviants leached detectable amounts of PGE, with thiourea in the no peroxide tests having ten times the concentration of PGE of the two other thio-lixiviants. The addition of peroxide decreased in PGE concentration, likely because of oxidation of the complexing thio-lixiviants. Ongoing two-step sequential leaching tests –