Probing the deep critical zone beneath the Luquillo Experimental Forest, Puerto Rico

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The interfaces where intact bedrock weathers to disaggregated material, such as saprolite and soil, are often hidden deep within the critical zone. The majority of weathering studies in the field focus on the shallow critical zone: soils, sediments, regolith, saprolite, and outcrops. However, weathering of primary minerals along bedrock fractures located in the groundwater or deep vadose zones may supply significant weathering products to streams and oceans.

We investigated the deep critical zone in the Bisley watershed in the Luquillo Critical Zone Observatory from two 9.6 cm diameter boreholes drilled with a hydraulic rotary drill to 37.2 and 27.0 m depth. Continuous core samples through coherent rock were taken using an HQ-wireline barrel. Bulk solid-state chemical analysis and powdered XRD were performed on rock and saprock samples. Thin sections were examined by optical microscopy and SEM. A history of low- to moderate-grade metamorphism is reflected by the presence of epidote, prehnite, pyrite, and tourmaline. Fresh rock contains abundant plagioclase and chlorite, with lesser quartz, K-spar, and pyroxene.Weathering rinds developed on fracture surfaces are porous and contain abundant secondary Fe(III)-oxides.

Drilled cores revealed repeated zones of highly fractured rock, identified as corestones, embedded within layers of regolith. Some corestones are massive and others are highly fractured. Subsurface corestones are larger and less fractured in the borehole drilled along the spine of a ridge, compared to the borehole drilled near a stream channel. As corestone size is thought to be a function of fracture spacing, the location of the valleys and ridges in the watershed may be controlled by the fracture spacing of the underlying bedrock.

Drilling terminated in coherent rock, thought to be bedrock based on a model that hypothesized a thickness for the corestone zone [1]. The 2 drilled boreholes and a resistivity profile [2] are only 20-50m apart and of similar elevation. However, all 3 have different profiles demonstrating that this is a complex landscape that needs both geophysics and drilling to understand. Even so, all of the profiles indicate that the weathering zone is well below the stream channel; thus weathering depth is not controlled by local base level. Furthermore, weathering rinds on fracture surfaces at depth indicate that water and oxygen are transported below the stream channel; thus not all of the water in the watershed is discharged to the stream.

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Efficiency of covers made of low sulphide tailings to control AMD from surface impoundments

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Introduction

It is now recognized that one of the best options to reclaim acid-generating tailings impondments is to use an oxygen barrier. Water contamination can be controlled by limiting the oxygen flux reaching the reactive tailings. Different types of oxygen barriers can be used, including engineered covers that rely on a high moisture content in one of its layers to prevent oxygen migration [1,2]. The authors work has shown that when appropriate soils are not available close to the mine site, low sulphide tailings can advantageously be used as a component of layered covers.

Main results

Different laboratory and *in situ* tests were performed over the last 20 years or so by the authors and collaborators to evaluate the response and performance of covers made with low sulphide tailings to limit water contamination. The initial series of tests used «naturally» low sulphide tailings as the moisture retaining layer in covers with capillary barrier effects (CCBE). Results showed that it was possible to maintain the water quality below the regulation criteria with such type of CCBE placed over reactive tailings. The control tests on exposed acid-generating tailings (without the cover) showed that the pH of the leachates droped below 3, with concentrations in dissolved metals in the hundreds of mg/l [3]. Another series of tests were performed in the laboratory to evaluate the feasibility of artificially producing the low sulphide tailings by a flotation process, and to use the desulphurized tailings as moisture-retaining layer in a CCBE. When the tailings are properly desulphurized, testing results showed that water contamination was effectively prevented, producing a leachate that meets water quality criteria [4]. An additional series of experiments were performed to evaluate the performance of monolayer covers made of low sulphide tailings, in combination with the elevated water table technique [5]. These column tests results show that the water table level is the most important parameter affecting the monolayer cover performance to control acid generation. The water table must be located at a minimum depth below the cover to prevent water contamination.

Conclusion

Results from different experiments at different scales showed that low sulphide tailings can be an efficient material to be used in engineered covers designed to control acid production from reactive tailings. In adddition, the use of low sulphide tailings valorises a mining waste and reduces the borrowing of natural soils and the related pertubations.

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