Baseline water quality at the Yanacocha Mine, Peru

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The Yanacocha Mine, located in the northern Peruvian Andes, is the largest gold mine in the world. The ore deposits occur in Tertiary dacite/andesite flow domes with extensive acid-sulfate alteration. Gold mineralization, accompanied by pyrite, enargite, and other copper sulfide minerals, resulted in elevated concentrations of As, Pb, Cu, Hg, Zn, and Mo in and around the orebodies. To define baseline water quality, water samples were collected from 20 stream locations unaffected by mining (13 mineralized, 7 unmineralized) over a 7-month period in 2002/03 that included portions of the rainy and dry seasons. Designations of mineralized and unmineralized were made using geologic maps, mineralogic information, and field observations. The baseline analysis included the influence of anthropogenic and natural impacts on water quality. Historical data collected by others, some of which covered periods before mining impacts began, were evaluated to determine pre- and post- mining-impact conditions. Data from the recent sampling and historical data were used to define baseline water quality. Even though mineralized streams had lower pH values, they generally did not contain elevated concentrations of toxic metals (e.g., Cd, Cu, Pb). However, examples of naturally elevated metals concentrations were found in all four basins (3 drain to the Amazon/Atlantic, 1 to the Pacific) in first-order streams, and some of these reaches would likely not have supported aquatic life before mining began. Concentration increases in SO_4, Ca, Cd, Cu, Pb, Zn, Fe, Al, and/or Mn and decreases in pH occurred in baseline streams in October-December, reflecting the first flush of metals and acidity from dried soils and salts with the onset of the rainy season. Results from the baseline analysis were used to discern the effects of mining on water quality at individual drainage and watershed scales.

Pre-mining ground-water quality at Molycorp's Questa molybdenum mine, Red River Valley, New Mexico

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Mineralized areas that host ore deposits, contain anomalously high concentrations of metals, sulfides, and sulfates. Prior to mining, weathering of minerals containing metal sulfides results in anomalously high concentrations of metals and sulfate in surface and ground waters. During remediation of mine-waste sites, the goal need not exceed pre-mining conditions.

The U.S. Geological Survey, in cooperation with the New Mexico Environment Department, is investigating the pre-mining ground-water quality at Molycorp's Questa molybdenum mine. The strategy uses a proximal analog, the Straight Creek catchment, which is underlain by hydrothermally altered andesitic and rhyolitic Tertiary volcanics similar to the mine site. Exposure of pyritized rock in the upper portions of the catchment produces acid rock drainage (pH 2.7-3.2) which infiltrates a colluvial debris fan and increases only slightly in pH (3.4-4.0). Infiltration of underlying bedrock produces ground waters of circumneutral pH (5.8-7.6). Both bedrock and debris-flow ground waters are Ca-SO4 type, often at or near gypsum saturation because of the abundance of secondary gypsum. As ground water travels down the debris-flow aquifer the dominant trend is dilution. Modeling indicates aluminum is initially leached from kaolinite, chlorite, and albite under acid conditions but thereafter the Al concentration is controlled by pH. Evidence for precipitation of both aluminum and silica is apparent at pH= or >4. Trace elements are weathered from specific mineral sources: Zn and Cd from sphalerite, Pb from galena, Co and Ni from pyrite, pyrrhotite, and chlorite, Cu from chalcopyrite, F from fluorite, and Mn from rhodocrosite. From these results a mass-balance calculation has been made for the development and evolution of ground-water chemistry in this mineralized and rapidly weathered mountainous catchment. Hence, the underlying processes that give rise to the Straight Creek ground-water compositions have been determined from mineralogy and modeling.

The results from the analog study were further compared to ground-water quality from other wells in similar terrain of the Red River Valley. The data compares favorably and provides a basis for the range of ground-water chemistry that likely existed before mining began.