11. GEOCHEMICAL CHARACTERIZATION

11.1 Introduction

The objectives of the geochemical characterization program are to predict the weathering and leaching behavior of materials that would be produced during typical mining and processing. The data produced from geochemical testing can be used to predict the chemistry of pore water in mine rock and representative tailings and to evaluate ML/ARD potential in any proposed operation and closure plans for mine-waste disposal in this area.

Samples for testing were selected to ensure that all the main Pebble Deposit rock types and that any lateral, vertical, and geochemical variability were represented. To date, as of 2010, the program had included analysis of over 600 rock samples from the Pebble West Zone, almost 400 rock samples from the Pebble East Zone, and 26 samples of overburden materials. In addition, almost 60 representative tailings samples from test processing of ore composites have been characterized.

Samples have been tested for mineralogical composition, acid rock drainage (ARD) potential (acid-base accounting), chemical composition, and contaminant mobility. Tests for the latter have included water contact tests, humidity cells, leach columns, and on-site field weathering (barrel) tests to evaluate rates of oxidation, acid generation, acid neutralization, and element leaching.

11.2 Results and Discussion

11.2.1 Rock

There are two main geological divisions at the site of the Pebble Deposit. The mineralization is hosted by sedimentary and volcanic rocks of pre-Tertiary age. After the copper and gold mineralization occurred, these rocks were partially eroded and later covered by other sedimentary and volcanic rock. These later Tertiary-age rocks do not contain economic mineralization.

Acid-base accounting has determined that pre-Tertiary mineralized rocks are dominantly potentially ARD generating (PAG). The acid potential is relatively high (sulfur content is typically more than 1 percent), and neutralization potential is limited. The majority of Tertiary cover and overburden materials have sulfur contents less than 0.1 percent and significant neutralization potential. These materials are typically classified as non-PAG. Results for the East and West Zones were broadly similar. Illustrative results of acid-base accounting for samples of pre-Tertiary mineralized rocks from the East Zone are shown in Figure 11-1.

To develop an understanding of weathering and leaching processes that might affect rocks exposed during mining (e.g., pit walls, stockpiled materials, waste rock), laboratory tests included humidity cell tests and subaqueous columns (Photo 11-1). Humidity cell test data were interpreted to estimate relative acid generation and neutralization rates, which in turn were used to define site-specific acid-base accounting criteria for segregation of PAG and non-PAG wastes. Based on the current interpretations, this criterion for both pre-Tertiary and Tertiary rock would be neutralization potential / acid potential = 1.6.

A second important waste management consideration is the time or delay to the onset of ARD. The delay occurs because, while waste materials may have a potential for generating ARD, they contain acid-neutralizing minerals that are not depleted instantly. The delay duration depends on the amount and availability of reactive neutralization potential and the rate at which this neutralization potential is depleted.

Based on data generated from humidity cell tests, samples with low neutralization potential to acid potential ratios (<0.1) would become acid within 2 years, whereas with neutralization potential to acid potential ratios of 1, the calculated time would be more than 20 years. Study of the characteristics of aged core materials (e.g., paste pH) suggested slightly longer times to acidification, up to 40 years. The calculations are consistent for laboratory and field conditions after consideration of differences in temperatures and suggest that for fully oxygenated mineralized pre-Tertiary rock, a decade or several decades might be expected to elapse before the onset of acidification.

Element release rates indicated by kinetic tests were mainly a function of leachate pH rather than the element content of the samples. Leaching of copper accelerated as pH decreased; therefore, the potential for metal release is linked to the potential for acid generation, and acid-base accounting data can be used to assess the potential for copper leaching. However, for some elements (e.g., arsenic, molybdenum, and selenium), release is significant under neutral pH conditions. Tests on some samples of Tertiary rock showed relatively elevated leaching of these elements under non-acidic conditions.

Qualitatively, the trends developing in the field tests (Photo 11-2) mirror those that have been observed in the laboratory tests.

11.2.2 Metallurgical Wastes

Ore processing, if based on a conventional flotation process to recover commodity-bearing sulfide minerals (chalcopyrite and molybdenite) followed by treatment of the pyrite for recovery of gold, would result in two tailings streams: a low sulfide bulk concentrate and a pyrite concentrate.

Low-sulfide bulk flotation tailings would be expected to have low potential to generate ARD provided the sulfide content remained below about 0.2 percent. Representative tailings from the East Zone have marginally greater ARD potential compared to representative tailings from the West Zone because of the lower carbonate mineral content of the former. In laboratory tests, element leaching from these low sulfide tailings occurred at low rates, and process supernatants were found to contain low levels of potential contaminants relative to water quality standards.

The pyrite concentrate would be expected to be PAG. To date, limited testing has been performed on the representative concentrate because possible designs for a metallurgical process are still at an investigative stage.

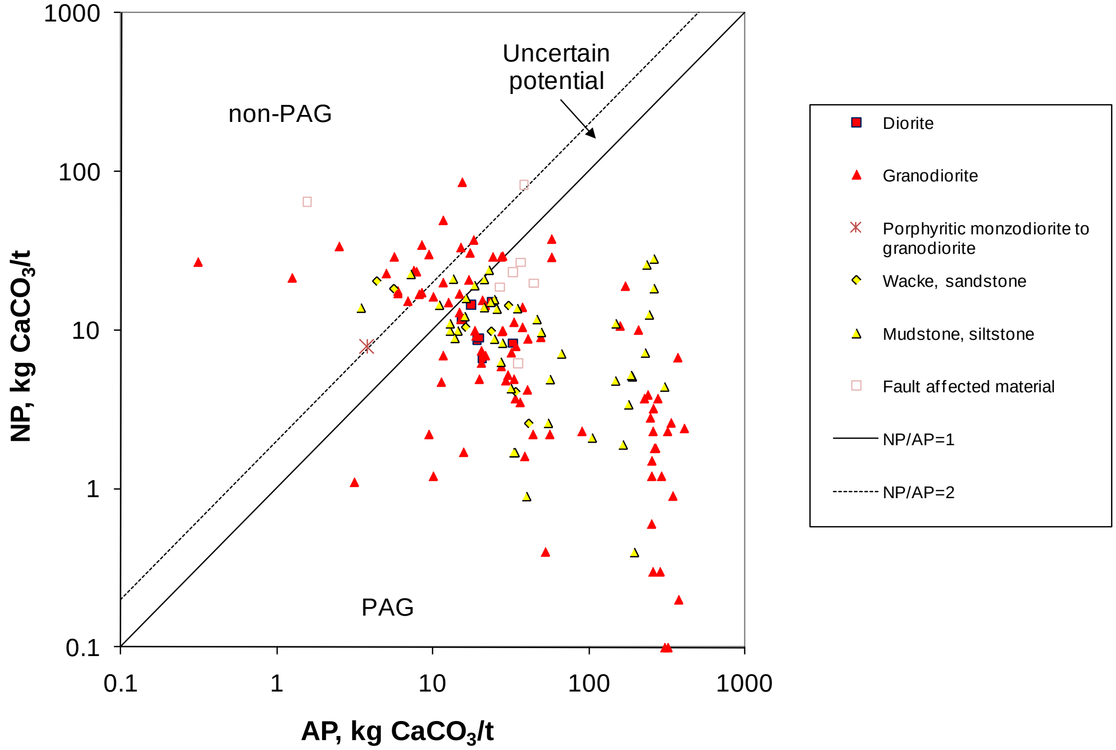

FIGURE 11-1
Acid-base accounting results for pre-Tertiary mineralized samples (Pebble East Zone)

AP = acid potential
$CaCO_3$ = calcium carbonate
kg = kilogram(s)
NP = neutralization potential
t = time

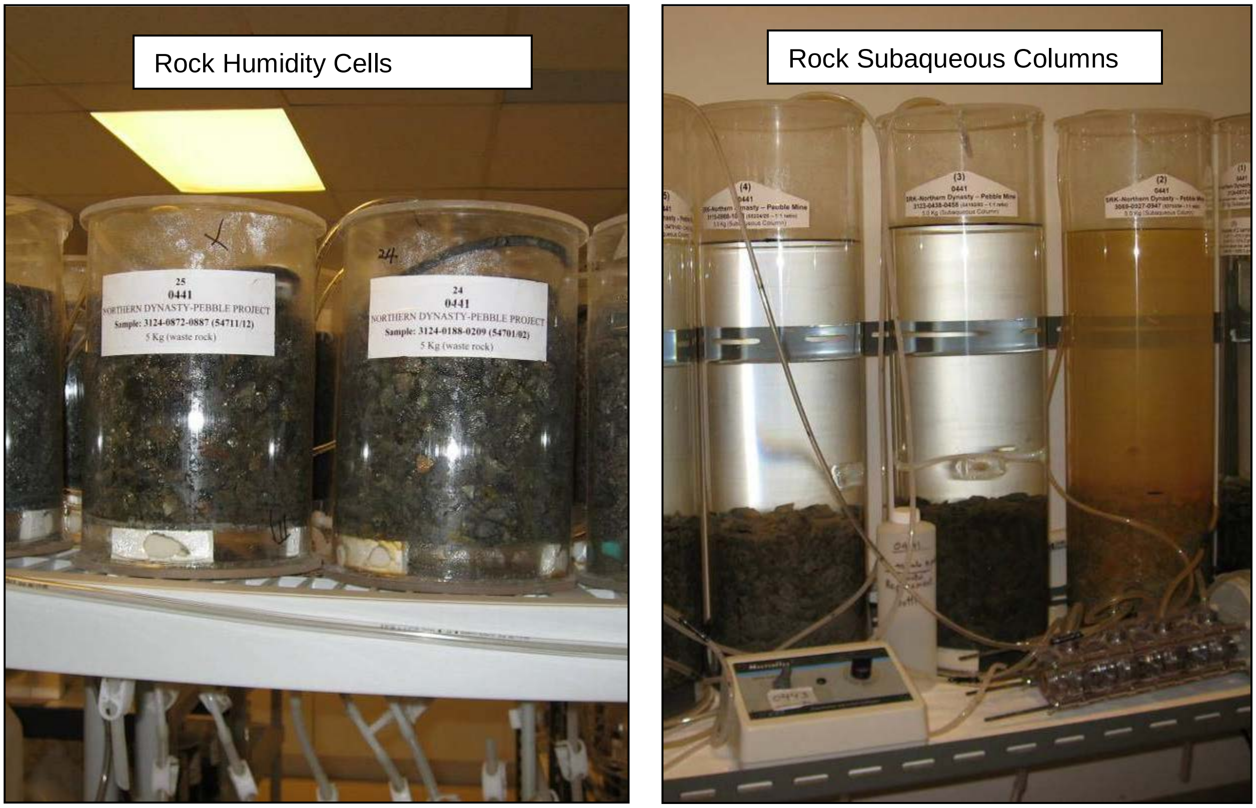

PHOTO 11-1. Laboratory tests included humidity cells and subaqueous columns.

PHOTO 11-2. Field weathering (barrel) tests were constructed on-site.