TECK COMINCO RESEARCH

MEMORANDUM

December 20, 2005

To:	Environmental Superintendent	(JKulas)
	Sr. Environmental Coordinator	(WHall)
	Environmental Coordinator	(JClark)
From:	Sr. Research Technologist	(SEJensen)
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SUBJECT: Proposal for Investigation of Mineral Weathering in Soils

Introduction

Teck Cominco Alaska Incorporated Red Dog Operations has an interest in investigating the effects of mineral weathering of fugitive particles within the mine's ambient air boundary.

The purpose of this investigation is to help address the State of Alaska's and Teck Cominco Alaska's concerns as to the relative contributions of various fugitive sources to ambient particulate levels. The preliminary investigation aims to determine whether mineralized particulates are present in the tundra and to determine their potential for leaching metal ions.

Background

The Red Dog mine is located in the DeLong Mountains in the Western Brooks Range with elevations ranging from 780 feet to 1500 feet above sea level. The Red Dog mine has been in operation since late 1989. The zinc and lead containing ore is upgraded to produce lead and zinc concentrates. Uneconomic ore, known as waste rock, is stockpiled. On-going work at the mine site has resulted in significant decreases in the release of zinc and lead-containing particulates to the environment.

Teck Cominco Red Dog mine conducted soil and vegetation investigations in 2003 and 2004 to evaluate the extent of the lead and zinc deposition. Emission inventories and air dispersion modeling are also being investigated to help better understand historic and existing fugitive particulate deposition. The data is intended to provide the State and Teck Cominco with information pertaining to the relative contributions of different sources of fugitive particulates.

Attention has been focused previously on quantifying fugitive particulates and evaluating sources. The potential of the particulates to affect local vegetation has not been studied in detail, but is planned. Soil sampling around the Red Dog mill, crushing and tailings areas has shown high lead to zinc ratios. The higher lead to zinc ratios in the soil samples suggest selective sphalerite oxidation is occurring, possibly through a galvanic mechanism. One result of the mineral oxidation is release of metal ions to and a change in soil pH in the surrounding environment. An investigation of weathered particulates is required to determine whether selective oxidation is occurring in the samples.

Objectives of proposed study

The proposed study is designed to answer the following questions:

- What form is the lead and zinc in the tundra surrounding Red Dog Operations?
- Is there any evidence for weathering in the mineral grains?

Outline of proposed project

Tundra soils will be collected from the site and then separated into fine and coarse size fractions and assayed. The mineral grains present in the different fractions will be identified by scanning electron microscopy (SEM). Mineral phases will be identified using X-Ray diffraction (XRD). Quantitative mineral identification will use a state-of-the-art mineral liberation analyzer (MLA). Leachable metals will be analyzed using diagnostic leaching using water and ammonium acetate. The potential for metal ion leaching over the longer term will be determined using kinetic cell testing. The work is to be mainly done at Teck Cominco Research, an independent facility to Red Dog Operations. The outline of the proposed experimental design should be considered preliminary as modifications may be required.

Detailed proposal

Sampling

Soil investigation protocols for exist to generate a statistically sound sampling program. The objective of this investigation is to determine whether weathering of lead- and zinc-containing particulates occurs in the area surrounding Red Dog Operations. This investigation will focus on a small set of samples obtained from impacted and non-impacted areas.

Soil samples will be collected from areas of the tundra around the concentrator where phytotoxic effects have been observed in the vegetation. The samples will be collected at two different depths. A "surface" sample representing the top 1 inch will be collected as well as a "mineralized" sample that will be collected one foot below the surface. The "surface" samples contain potentially 90% vegetation/detritus and 10% inorganics. The "mineralized" sample represents the naturally mineralized soil; approximately 90% clay and other inorganics. Another set of soil samples will be collected in the same manner from the tundra at a distance of 3.5 km from the concentrator where no phytotoxic effects are observed in the vegetation. A sample will be collected from within the gyratory crusher building located adjacent to the concentrator. This sample represents the freshest particulates that could be deposited onto the tundra and could be used as a reference sample. Sample locations are given in Figure 1.

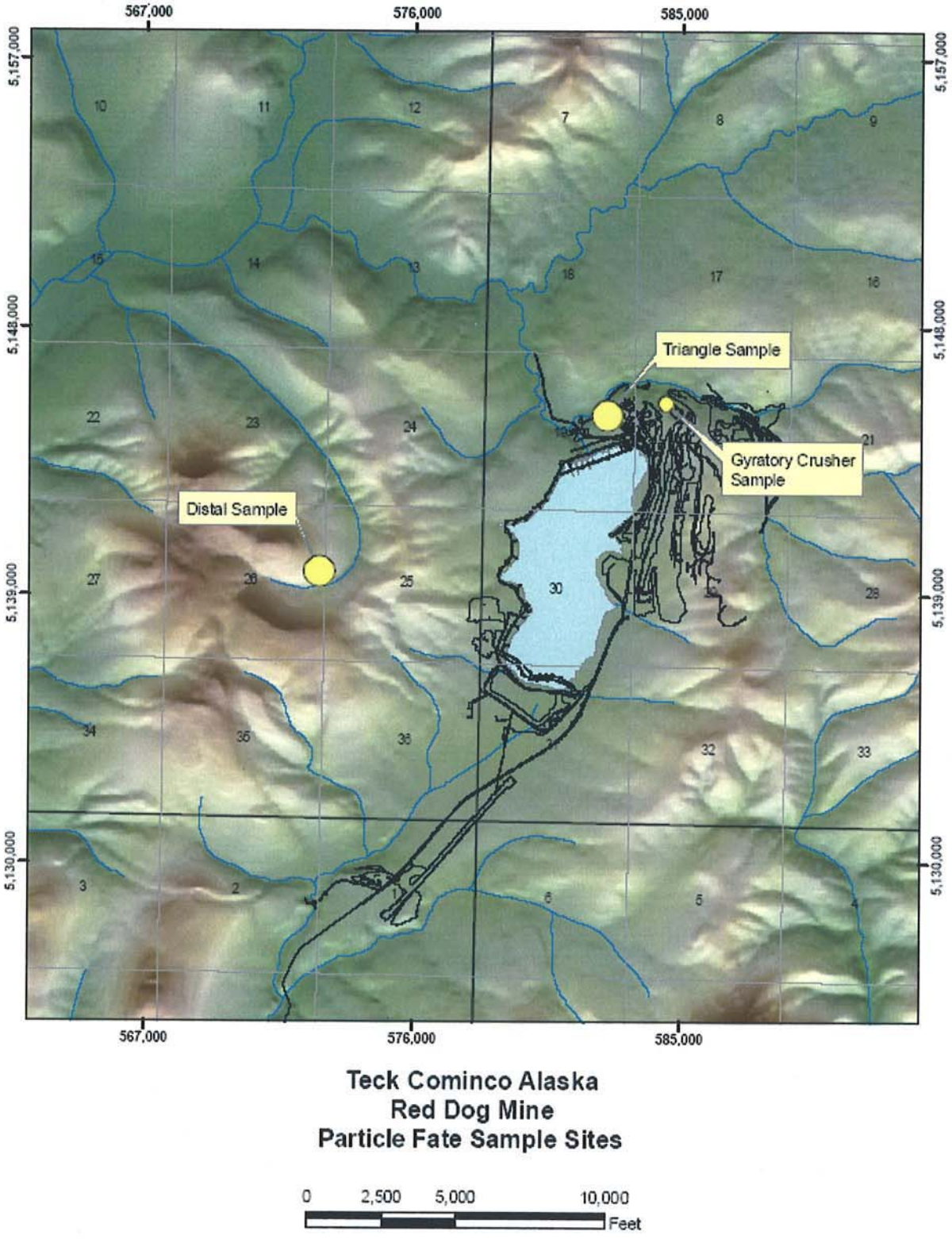

Figure 1. Location of sampling sites.

Sample preparation

All five samples will be subjected to the same methodology and comparisons will be drawn from analyzing the results of the combined data. Sample analyses will follow the protocol in Figure 2. The samples will be dried at 50°C and sealed in moisture-tight jars for transportation. The moisture content will be determined by weighing a sample before and after drying.

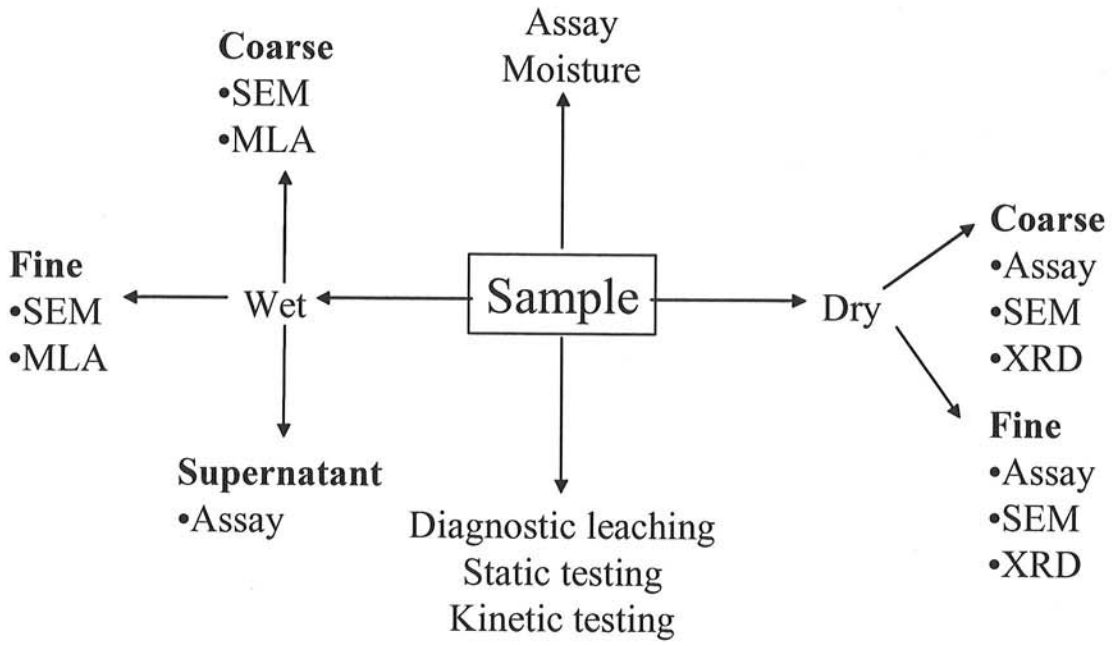

Figure 2. Sampling methodology for soil samples in this investigation.

A known mass of sample will be dry screened into fine (-75μm) and coarse (+75 μm) fractions. Before screening begins the large clumps within the sample will be size-reduced using an agate mortar and pestle. The covered sample will be placed on a 75 μm screen over a collecting pan and rototapped for 30 minutes. Time will be allowed for the fines to settle and then the weight of each fraction will be determined. A representative sample of each fraction will then be analyzed for mineral content using inductively coupled plasma optical emission spectrometry (ICP). The analysis will be performed by Teck Cominco Trail Operations Analytical Services, a certified lab routinely involved with environmental analysis. The coarser and finer fractions will be separately assayed.

A quantity of organic material is likely to be associated with each size fraction. Removing fine mineralized particles will require a separation step between the coarser organic and finer inorganic components. A 1 g sample will be shaken in 25 mL water for 10 minutes. The resulting suspension will be centrifuged at 3600 rpm for 30 minutes. The solutions will then be collected and analyzed by ICP. The residual solids will be collected and air dried.

The dried solids from the wet separation method above will be mounted in epoxy resin using standard methods. The mounted samples will be gold coated and analyzed by SEM and MLA. Given the limited number of samples in this study, sampling statistics will be generated only on the results of the MLA study.

Analytical techniques

X-ray diffraction (XRD) is a technique used to identify the mineral phases of a substance. This type of analysis will be used on the different size fractions to determine if oxidation products/minerals (e.g anglesite/galena for lead and sphalerite/smithsonite for zinc) are present. The gyratory crusher sample will be ground in an agate mortar and pestle and the sample mounted in the XRD instrument. The scanning 2θ range is 15° to 75°, previously determined to be suitable for identifying mineral phases in Red Dog ore.

SEM is used for mineral identification and quantification. The magnification is up to 10,000 times. This type of analysis will be used to determine sulfide mineral weathering characteristics. The weathering will be determined by elemental analysis of individual spots on mineral grains as well as from the grain morphology.

The MLA is an SEM based image analysis system. Some of the important components of an MLA include energy dispersive spectral (EDS) X-ray analysis and a backscatter electron (BSE) detector. An MLA is capable of automatically discriminating between mineral/phases based on the mean atomic number (BSE brightness), elemental composition (X-ray analysis) and a suite of reference samples. This cutting-edge technology will be used to provide quantitative mineral identification.

The availability of metal ions and potential of metal ion leaching may be estimated using diagnostic leaching. The method follows that developed in-house to determine the proportion of oxidized lead in Red Dog ore using ammonium acetate/ ammonium chloride as the leachant. The leachant contains 37.5% ammonium acetate and 0.5% chloride. This reagent is used to leach oxidized lead such as lead sulphate, lead carbonate and lead oxide, however not lead sulfide. A slurry is formed by adding 1 g of the sample to 1 L of leachant and reacted under nitrogen for 30 min. The lead concentration of the leachate is determined by ICP. The amount of oxidized zinc may also be determined using this method.

The remainder of the tundra samples not used for analytical work at Teck Cominco Research in Trail will be sent to Canadian Environmental & Metallurgical Inc. This is an accredited lab for environmental analytical analysis. The weathering potential of the samples will be addressed using static testing. The theoretical potential for metal ion leaching may be determined by assaying inorganic carbon and sulfide sulphur. The analyses are used to determine the acid generating and neutralization potential (AP and NP, respectively).

The remaining surface soil samples will be subjected to kinetic cell testing. The time dependence of metals leaching will be estimated using a standard protocol. This protocol was originally developed to determine the acid generating potential for wasterock. A non-standard humidity cell may be required, depending on sample remaining for the analysis.

Presentation of results

The results of all analytical data will be contained in a report that fully documents the materials used, methods employed, data obtained and its interpretations.

Study schedule

The proposed study will be conducted during summer 2005 with analysis in late 2005 and reporting in 2006. Below is the estimated schedule for completing the various stages of the study

- Soil sampling (August 2005)
- Protocol endorsement (December 2005)
- Submit initial report of findings (January 2006)
- Submit final report of findings in the project (March 2006)

Outcomes

The outcome of the investigation will be identifying mineral grains in samples of the affected and unaffected areas. The degree to which metal ion migration has occurred will be determined from the analytical investigation. The degree of mineral weathering will be determined from the SEM and MLA investigations. The mineral associated with organic matter will be estimated from the analytical results. Finally the availability of metal ions will be determined from the diagnostic leach and kinetic testing results. A good picture of the mechanisms of metal ion leaching can be determined from these investigations.

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