

# Evaluation of Solid-Phase Analytical Techniques for Chemical Elements Used in the Proposed Ajax Mine EIS

prepared for:

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## 1. INTRODUCTION

During a mining project, rock from a stable underground environment is blasted and moved to the surface. Only a small portion of that rock becomes a saleable product; the remaining mined rock becomes waste material as either waste rock or tailings. Waste rock is the portion of the mined rock that does not have an economic value, and is therefore not processed. Tailings are the waste product created from the crushing, milling, and extraction of metals from ore grade material. Waste rock materials are stored in waste rock management facilities (WRMF), waste rock dumps, or stockpiles. Tailings are stored on tailings storage facilities (TSF), or impoundments. A TSF is often made up of embankments that are usually built from either waste rock or cycloned tailings. The proposed Ajax mine will have both a TSF and multiple WRMFs, and produce an estimated 440 Mt of tailings and 1,100 Mt of waste rock (Ajax EIS, Section 3.8.4 and Table 3.9-1 respectively). Overburden will also be stored and occasionally moved around at the proposed site.

Both waste rock and tailings at the proposed Ajax mine, and their respective storage facilities, are potential sources of water contamination. Blasting of in-situ rock creates new rock surfaces. These new rock surfaces are exposed to both physical and chemical weathering. Chemical weathering, such as oxidation, can occur when the rock surfaces are exposed to air and moisture. The reaction products, produced during the chemical weathering process, can leach metals and elements of concern into surrounding water causing contamination. During physical weathering, the rock particles break down through physical processes exposing new surfaces. These new surfaces can then chemically weather causing additional contamination in an ongoing cycle until the metals and elements of concern are effectively depleted.

When making predictions of future water quality and air quality at a proposed mining project such as Ajax, it is very important to accurately quantify the solid-phase levels of metals and other elements contained within the rock. To achieve this, rock samples are often collected, ground, dissolved in strong acid during a digestion process, and analyzed on specialized analytical equipment.

The complete dissolution of the rock samples through digestion is a very important step. If the minerals within the rock sample are not completely dissolved, the analytical data does not accurately represent the chemical composition of the sample, and therefore the rock to be mined.

This chemical composition, the solid-phase levels of metals and other elements in rock, will become part of the basis for the prediction of future water quality and air quality at the minesite. Obtaining an accurate understanding of the solid-phase composition of the rock is an important first-step in estimating potential water contamination.

## 2. ANALYTICAL METHODS FOR SOLID-PHASE ANALYSES IN THE AJAX EIS

There are various methods for determining the chemical composition of rock. Many of the most common, and most cost-effective, methods involve the digestion of a finely ground rock sample in a mixture of strong acids. One such acid mixture is known as "aqua regia", a 3:1 mixture of two acids, hydrochloric (HCl) and nitric (HNO<sub>3</sub>) acids.

A stronger, more effective, acid mixture used for digestion is a four-acid mixture of nitric (HNO<sub>3</sub>), perchloric (HClO<sub>4</sub>), hydrofluoric (HF) and hydrochloric (HCl) acids. Sometimes called multi-acid digestion, the four-acid digestion method is considered a "near total" digestion of rock samples. The four-acid digestion method is also a very effective dissolution procedure for multi-element analysis at trace levels of detection.

The type of acid mixture selected for sample digestion will depend on: 1) the type of sample (soil, sediment, sludge, rock, etc.), and 2) the type of information required.

Historically within the mining industry, aqua regia digestion was the standard for determining the solid-phase levels of precious metals and other elements contained within a rock sample. However, it is now recognized

that four-acid digestion yields more accurate and representative data on the total solid-phase content of a rock sample.

It is currently understood that it is not only important to determine the levels of economic components, such as copper or gold, but also the levels of other elements that may lead to contamination of the concentrate after milling and result in smelter monetary penalties. These elements can include arsenic and mercury. Additionally, mining companies are realizing that a reliable database of major and minor element geochemistry obtained from four-acid digestion analyses can prove to be a valuable tool when creating block models and in alteration mapping.

The Ajax Project Feasibility Study Update of February 2016 (page 84) explains that four-acid digestion was used for KGHM Ajax Mining Inc. (KAM) assay samples. Unfortunately, that sizable database of solid-phase element data was not incorporated into the environmental predictions prepared for the proposed Ajax mine in its EIS.

Two-acid aqua regia digestion data is sometimes said to reflect the “environmentally leachable” portion of the sample. The “environmentally leachable” portion of a sample is applicable in situations where the leachable content of a sample is considered most important, such as during a contaminated-sites investigation, and when the total composition of the material is not required. However, environmental studies done during the development of a proposed mining project, such as Ajax, result in predictions of water chemistry and air quality. They require more detailed information than the level of “environmentally leachable” components in the rock.

Mined rock is blasted from a stable underground environment, creating material of varying sizes with newly exposed surfaces that are susceptible to ongoing oxidation and leaching. For example, sulphide minerals can be present in mine rock and tailings, as they are at Ajax (EIS Appendix 3-A). Sulphide minerals release metals as they oxidize. Since this is an ongoing process as the rock weathers, it is recommended that a four-acid digestion method be used for proper solid-phase content characterization of the rock. Accurately knowing the solid-phase content of elements within the rock allows for more realistic predictions of water quality, air quality, and metal release over time.

The EIS for the proposed Ajax mine has hundreds of environmental solid-phase component analyses. Unfortunately, KAM chose to use the weaker two-acid aqua regia digestion method when doing their environmental geochemical testwork, and this data became the basis for their predictions of water quality and air quality.

Silicate minerals, like those at the proposed Ajax mine, contain trace metals and other elements of concern. When they weather and leach, they release those trace metals and elements of concern into the environment. Silicate minerals are sometimes thought to be non-leachable because they do not have a significant rate of dissolution in stable aquifers. However, silicates can dissolve slowly under both acidic and non-acidic conditions, and can provide neutralization for acidity. The silicate minerals present at the proposed Ajax mine have been found to leach relatively quickly as discussed in the EIS, Appendix 3-A as follows:

Page 4-7: A number of silicate phases, including actinolite, clinocllore, biotite, vermiculite, epidote, serpentine, talc and olivine were identified.

Page 4-13: All ore and tailings samples contain a number of silicate phases known to have acid neutralizing capacity, including plagioclase, clinocllore, clinozoisite and vermiculite.

Page 6-3: “A few cycles from HC3 show pH values as low as 6 but are more typically observed between pH 6.5 and 7.5. This indicates that in CaNP-depleted SLD material of median S content, sulphide oxidation is sufficiently slow, and/or silicate buffering sufficiently fast, to keep drainage pH neutral over extended periods of time. At higher S contents, silicate minerals are still capable of buffering drainage between 5 and 6.”

Page 6-19: “ABA measurements indicated that neutralization potential may be available from silicate minerals in addition to carbonates contained in the Ajax samples (Section 5).”

Page 6-20: Table 6-3 indicates that several fast and intermediate weathering silicates have been identified in Ajax mine rock.

Page 6-24: “The observed signature suggest that several silicate minerals are weathering and attenuating acidity released from pyrite in the SLD rather than a single mineral.”

Page 7-1: “MAFV and PICR rock however show variable but systematically higher modified NP values, indicating the presence of a more reactive silicate NP mineral assemblage than found in the SLD unit.”

Page 8-3: “Another distinct signature is that the silicate-buffered high-S SLD humidity cell with a pH<6.0 produces the highest dissolved metal (Cd, Cu, Ni, Zn) and the lowest oxyanion (As, Mo, Se and V) leach rates of all the cells.”

As the above quotations indicate, mine rock and tailings at the proposed Ajax mine contain silicates of notable reactivity, which can release metals and elements of concern to the environment. Since silicates have been found resistant to aqua regia resulting in incomplete digestion (Griepink and Tölg, 1989), the use of hydrofluoric acid (HF) as a complexation reagent in the four-acid procedure allows for a more complete dissolution of silicate minerals and the trace elements bond within them. More complete dissolution of the silicate minerals will provide a better characterization of the mine rock and therefore better predictions of water quality.

Another method used to determine the “total” elemental composition of a sample is whole rock x-ray fluorescence spectroscopy (XRF). This method does not require digestion, instead an ignited sample is combined with lithium borate and fused to form a glass sample disc. Specialized instrumentation is then used to subject the sample disc to high-energy, short wavelength x-rays or gamma rays. The radiation excites the elements within the sample disc, this causes the release of secondary radiation, the fluorescence, which is then measured.

Although not discussed in any detail within the Ajax EIS, page 5-42 contains a brief discussion of whole rock XRF analysis for fifteen samples from five field-bin kinetic tests, and is presented in Table 5-13 on page 5-43.

### **3. COMPARISONS OF SOLID-PHASE ANALYSES BY DIFFERENT METHODS IN THE AJAX EIS**

To see the effect that the analytical methods have on the analyses of rock, tailings, and overburden at the proposed Ajax Project, the results of one method can be compared with those of another on the same sample. This is difficult to do for the Ajax Project, because results by two or more methods are not highlighted in the Ajax EIS. Nevertheless, there are a few comparisons that can be made.

A comparison of the aqua regia digestion and whole rock XRF methods can be made using data provided for the field bins, Figures 1 and 2 were made using that data. The data can be found in Appendix C-1.10 on page C-1.10-1 and Table 5-11 on page 5-43, respectively.

Figures 1 and 2 show there is a significant difference in both aluminum and potassium data between the two analytical methods, with XRF results nearly always significantly higher. Only a few elements in the Ajax EIS were analyzed by XRF. Nevertheless, the large differences in element content for those elements raise concerns that aqua-regia-based levels used to make predictions in the EIS are significantly underestimated.

Further to this point, a comparison of the XRF analytical method (using a portable XRF analyzer) and the four-acid digestion method is shown in Figure 3. The comparison was done and reported by a testing laboratory.

This comparison reinforces the concern over the use of two-acid aqua regia digestion methodology for analyzing Ajax environmental samples. The figure shows good correlation between the XRF and four-acid digestion methods, supporting the conclusions that the aqua regia data shown in Figures 1 and 2 is notably underestimated.

A limited comparison can be made between two-acid aqua regia results and four-acid results from the Ajax EIS. Figure 3 is a reproduction of Figure 11.5-6 from Section 11 of the EIS, page 11.5-14. This is a comparison of four-acid digestion assay data and aqua regia data for a number of environmental samples including four humidity cells. Like Figures 1 and 2, Figure 3 clearly shows significant discrepancies between analytical methods, with the aqua regia data underestimating the arsenic content of the samples tested. This again raises concerns about all reported aqua regia data and the predictions and conclusions based on that partial-digestion data.

Since KAM has a large four-acid digestion assay database, this data should be used to re-evaluate the environmental predictions and conclusions submitted in the EIS. Unfortunately, Slide 54 in the February 18, 2016, company presentation to the Community Advisory Group explains the Ajax assay database will not be released, and that “considerable environmental sampling data has been included to support the Environmental Assessments”.

However, there is no discussion about the discrepancies between analytical methods, and that the environmental two-acid aqua regia analyses may not be sufficient to support the EIS conclusions properly. To illustrate this point, Section 11.5.3.7 of the EIS explains that solid-phase arsenic can affect how much arsenic is released to water. When looking at Figure 3, it can be seen that values obtained from the four-acid digestion method can be up to, or more than, ten times higher than those obtained using the aqua regia digestion method. Considering that the EIS predicts levels of contamination and estimates risk to human health and the environment, a reassessment of the presented conclusions should be done using the more appropriate four-acid digestion method data.

#### **4. WINDBLOWN DUST**

In addition to the concern about metals and other elements of concern leaching into minesite waters, there is also a concern about wind blown dust from the proposed Ajax minesite. This dust would originate from blasted rock, tailings, and overburden. Without full and accurate characterization of these materials, including the true total metal content of the mine materials, the proponent is not able to make accurate predictions about the total amount of metals and elements of concern that may be blown from the minesite onto the surrounding lands. If the amount of a parameter such as copper is not accurately estimated, then the impact to the surrounding environment and human health cannot be estimated.

#### **5. CONCLUSION**

Although throughout the EIS, the predictions of environmental impact are considered conservative, the data presented in this document questions those conclusions. An evaluation of the analytical methodology, and the implications of the underestimated solid-phase metal and elements of concern content for the predictions presented should be provided.

#### **REFERENCES**

Griepink, B. and Tölg, G., *Sample Digestion for the Determination of Elemental Traces in Matrices of Environmental Concern*, Pure & Appl. Chem., Vol. 61, No. 6, pp. 1139-1 146, 1989.

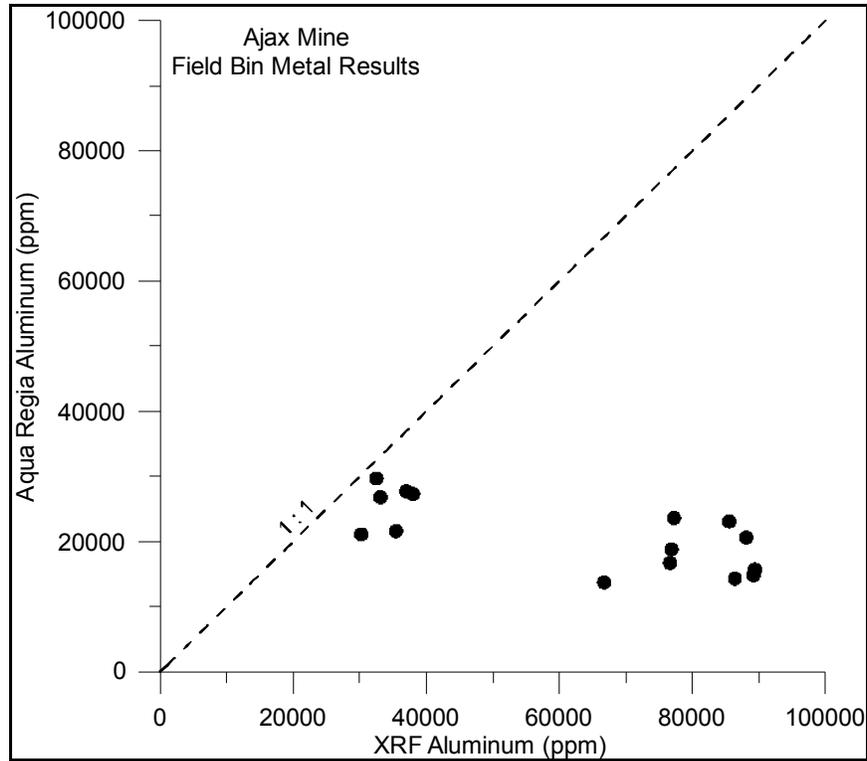


Figure 1: XRF vs Aqua Regia Aluminum in Ajax Field Bin Samples

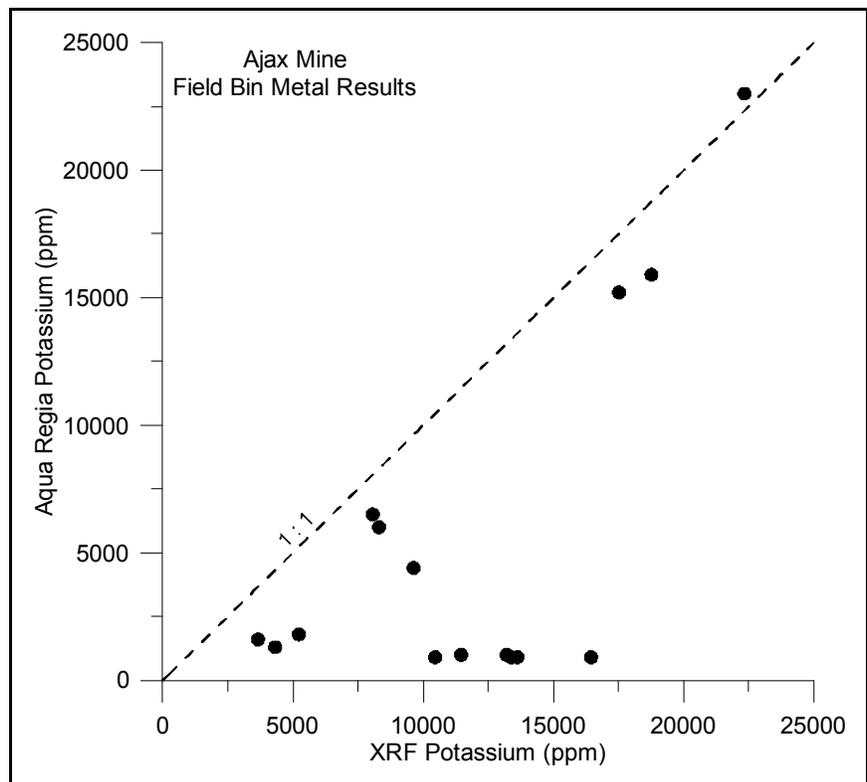


Figure 2: XRF vs Aqua Regia Potassium in Ajax Field Bin Samples

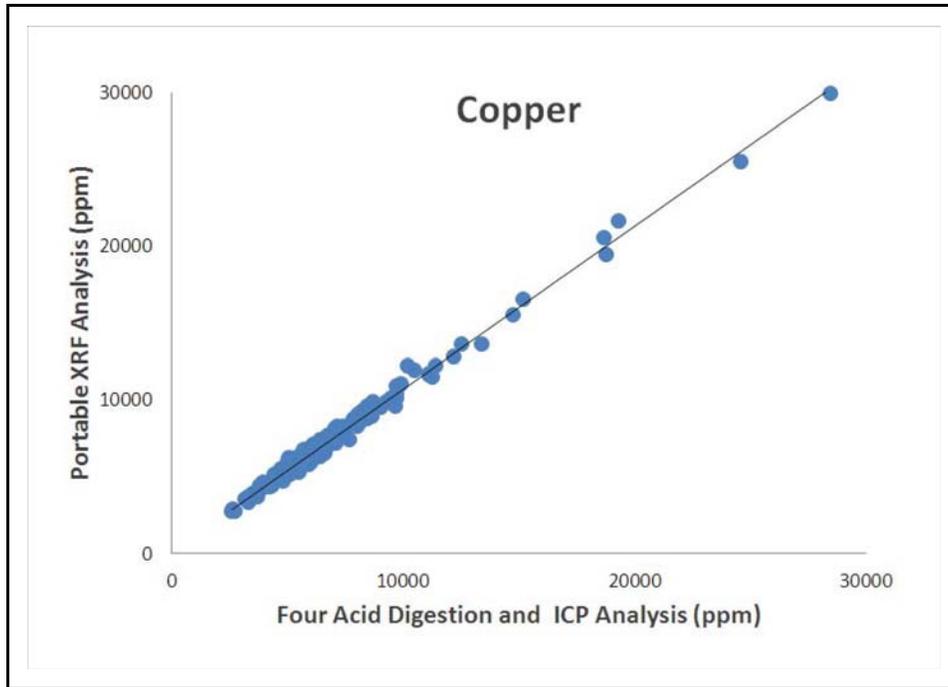


Figure 3: Plot of copper results by portable XRF vs four-acid digestion ICP-OES for copper porphyry samples. Taken from ALS Geochemistry Portable XRF Analysis Technical Note 2014.

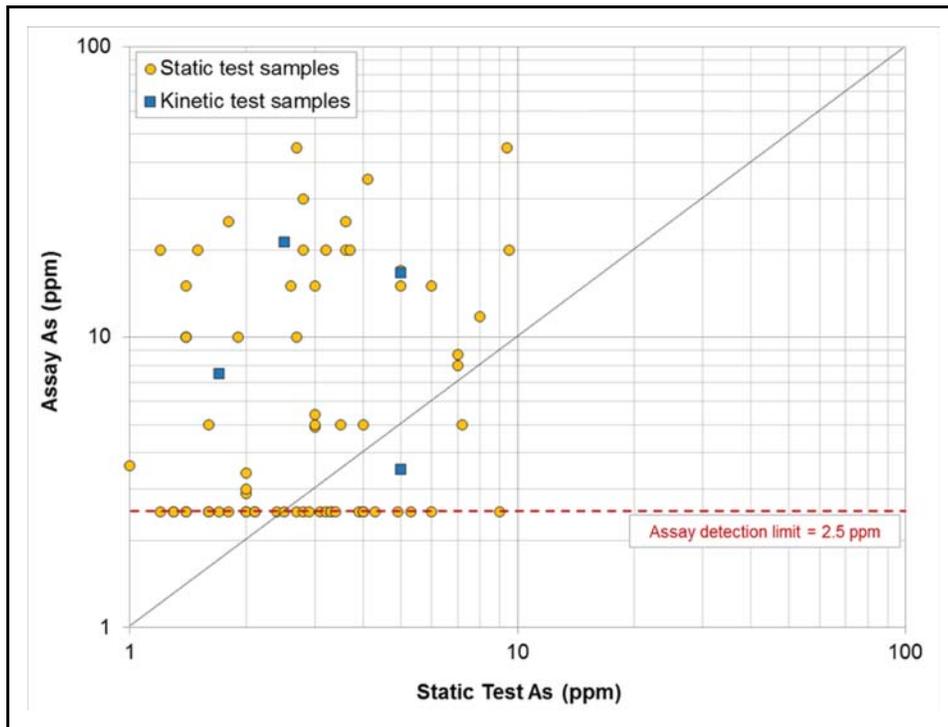


Figure 4: Taken from Ajax Mine EIS, Section 11, Figure 11.5-6