Mining Related Environmental Database for West Coast and Southland: Data Structure and Preliminary Geochemical Results.

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Abstract

Geochemical data related to AMD for the West Coast and Southland regions have been collated into a relational database and GIS system. The types of information include; rock geochemical data, water chemistry data and aquatic macro-invertebrate abundance data. This information will be combined with eco-toxicology experiments to determine impact thresholds on aquatic ecosystems. Ultimately these datasets will be combined with remediation investigations to produce a Framework to assist decision making related to mine planning, consent and compliance.

Current geochemical research examines the controls on As concentrations downstream of gold mining areas and the variability of AMD from Brunner Coal Measure rocks. Assessment of factors that control the chemistry of Brunner Coal Measure AMD such as mine type, hydrogeology, geology, geochemistry and climate is in progress. Minerals that control the concentration of aluminium downstream of AMD point sources include alunite, jurbanite and various forms of $Al(OH)_3$.

Keywords: *geographic information system, relational database, acid mine drainage (AMD), acid rock drainage (ARD), acid base accounting, geographic information system (GIS), Framework.*

Introduction

Oxidation of sulphide minerals, especially pyrite, during weathering can cause Acid Rock Drainage (ARD) and release iron (Fe), sulphate (SO_4), acid (H^+) and trace elements, such as nickel (Ni) and arsenic (As), into the aquatic environment. The efficiency and intensity of ARD forming processes are often increased by mining related disturbance because large volumes and surface areas of sulphide-bearing rocks are exposed to weathering processes. When mine disturbance contributes to ARD processes, the downstream effect is usually referred to as Acid Mine Drainage (AMD).

The chemistry of ARD can be substantially influenced by secondary reactions with other rocks and minerals in the ARD environment. Reaction between ARD and clay minerals can increase the aluminium (Al) concentration in the aquatic environment, for example, AMD in Mangatini Stream downstream of Stockton Mine (Lindsay et al., 2003). Reaction between ARD and carbonate minerals in surrounding rocks can neutralise acid but leave elevated trace element concentrations downstream from mines. For example, arsenic concentrations in Soldiers Creek, Snowy River (Brown et al., 2003; Noble et al., 2002) and Blackball Creek catchments (Haffert and Craw, 2005) are elevated around historic mine and mineral processing areas.

The impact of AMD and trace element enriched mine drainage on aquatic ecosystems is one of the most challenging environmental issues facing the mining industry (Plumlee and Logsdon, 1999). Current research conducted by CRL Energy, Landcare Research, University of Canterbury and Otago University will determine geochemical and biological criteria to establish impact thresholds in aquatic ecosystems in the West Coast and Southland regions. These criteria will be combined with research into optimal remediation technologies for AMD and trace element enriched mine drainage. Geochemical, biological and remediation research will be combined into a Framework to assist decision making in mine planning, consenting and compliance in the West Coast and Southland regions.

Geochemical data relating to rocks commonly disturbed by mining and water chemistry information downstream of mines is currently being collected and interpreted to identify water quality risks related to mining activity in the West Coast and Southland regions. This process involves compilation of all previously collected data into a geographic information system (GIS), identification of deficiencies in current data sets and collection of new datasets where gaps are identified.

Database Contents

Geochemical and biological data related to ARD and AMD for the West Coast and Southland regions have been collated into a relational MS Access database. The types of information include; rock geochemical data, water chemistry data and aquatic macro-invertebrate data.

Rock geochemical datasets include acid base accounting (ABA) analyses to predict the amount of AMD generated by rocks disturbed during mining, such as:

- MPA; Maximum Potential Acidity
- ANC; Acid Neutralising Capacity
- NAPP; Net Acid Producing Potential
- NAG; Net Acid Generation
- Paste pH

Major and trace element analyses are also included where available. The database can be expanded to include kinetic test results used to examine AMD generation with time.

Water chemistry datasets include stream physio-chemical parameters and total/dissolved concentrations of major cations, major anions and trace elements. These analyses have been collected from AMD point sources, AMD impacted catchments and background catchments without mining activity.

Aquatic macro-invertebrate datasets have been collected in association with the University of Canterbury and include species abundance and diversity information. These datasets are being correlated with water chemistry information and eco-toxicology experiments and will be used to determine impact thresholds for aquatic eco-systems (Harding, 2005).

Database Structure

The database structure consists of three related tables for each type of data; a Site Information Table, a Sample Information Table and a Metadata Table.

- Site Information Table includes a unique identifier for the sample collection site and all site specific information such as NZMG co-ordinates and description
- Sample Information Table includes a unique sample identifier, the appropriate site identifier, the date and time of collection and all analyses specific to that sample
- Metadata Table includes a unique metadata identifier and information relating to the data source and modifications to the data.

The Site Information Table is linked the Sample Information Table through a one-to-many relationship so that multiple samples can be collected at the same site and temporal variations can be examined. The Metadata Table is linked to the Sample Information Table through a one-to-many relationship reflecting multiple samples from the same data source. Data logger information for water quality is separated from other water quality analyses to improve the efficiency of data management and retrieval.

Selected information from original data sources are also included, for example, old sample site codes, analyses numbers and some laboratory information. These can be useful when querying the data base.

GIS Functionality

ArcView 9.0 Geographic Information System (GIS) software is used to spatially display and analyse data in the environmental database.

The MS Access tables are easily imported into ArcView as DBF tables and sample locations are mapped spatially using the NZMG coordinates. The non-spatial analytical data are then related to the spatial data by the Site ID field. The connection established between the spatial data and the non-spatial analytical data provides a method for efficiently displaying, querying and retrieving data within the GIS environment.

Single or multiple datasets, such as geology, topography and GERM (GNS Mine Information) can be added to the GIS together with AMD data to examine the spatial relationships between datasets. Attribute tables can be queried to highlight sample locations with specific features, for example sample sites where AMD or ARD occurs can be highlighted by selecting sample sites where pH is less than 3. Using these tools, spatial relationships between datasets can quickly be assessed and analysed. Similarly, SQL queries can be written in ArcView for more sophisticated analyses.

Where appropriate, the Site Information Table also contains drill hole information including, hole orientation, depth and sample intervals. This data can be exported and used for three-dimensional modelling and analysis.

Geochemical Research Summary

In general, the AMD related geochemical dataset for the West Coast lacks detail. There are several notable exceptions around active mine sites and at specific areas that have been the focus of previous research such as Sullivan Mine Site (de Joux, 2003; de Joux and Moore, 2005; Trumm et al., 2003; Trumm et al., 2005). ABA rock geochemical data is mainly restricted to current mine and exploration areas and there are few ABA analyses from historic mine sites. Trace element enriched drainage from gold mines have been identified (Noble, 2003); and Arsenic is commonly the trace element of concern.

Water chemistry data is widely distributed and there are physiochemical measurements at many locations. More detailed laboratory analyses have sometimes been collected from streams that drain mines (James, 2003) but less have been obtained from AMD sources. Detailed characterisation of AMD chemistry and trace element enriched mine drainage at sources is important to be able to link rock geochemistry to downstream water chemistry and to determine remediation strategies (Trumm et al., 2003).

Gold Mining Related Research

Acidity problems related to gold mining in Greenland Group Rocks are minimal because these rocks have a high acid neutralising capacity (Hewlett and Craw, 2003; Woodward-Clyde, 1994). However, Arsenic concentrations can be elevated within the mineralization that hosts gold deposits and possibly in streams that drain historic gold mine areas. In some cases, the concentrations of Arsenic are substantially above drinking water guidelines in streams that drain gold mine or mineral processing areas (Brown et al., 2003; Haffert and Craw, 2005; Hewlett and Craw, 2003; Noble et al., 2002).

Natural arsenic enrichment of catchments in un-mined areas and arsenic enrichment downstream of historic gold mining activity are being studied in collaboration with Otago University. Relationships between mineralization types and downstream trace element concentrations are also being examined. Current research is aimed at identifying risks to water quality posed by current and future gold mining in the West Coast and Southland regions. These data will be incorporated in the Framework to assist with future mine planning.

Coal Mining Related Research

Active and historic coal mines hosted in the Brunner Coal Measures (BCM) cause most AMD problems on the West Coast (Black et al., 2005; Lindsay et al., 2003; Trumm et al., 2005). BCM and other sediments surrounding coal contain pyrite and often have a high acid producing potential and low acid neutralising potential (Hughes et al., 2004).

Within AMD produced by the BCM, several physiochemical parameters have implications for downstream aquatic ecosystem impacts including pH and metal concentrations (Harding, 2005). Metal concentrations (especially Fe and Al), pH, oxidation state and trace element concentrations in undiluted AMD also have implications for selection of optimal remediation technologies (Trumm et al., 2003). Currently, the variability of these parameters from BCM AMD is being studied and their relationship to impacts on aquatic ecosystems assessed. The data collected will be used to determine risks to water quality posed by future mining and incorporated into the Framework to assist with future mine planning on the West Coast.

Preliminary Geochemical Interpretation of Brunner Coal Measures AMD

The concentrations and proportions of Fe and Al in AMD (Figure 1) produced by the BCM are important physiochemical parameters for several reasons:

- Acid producing hydrolysis reactions for these abundant metals
  e.g. $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$
- Acid storage in unstable secondary minerals, e.g. jarosite
- Toxic effects on aquatic biota

Factors that influence the concentrations of Fe and Al in AMD, include, geochemistry, geology, mine type, hydrogeology and climate. The interplay of these factors and their implications for AMD management are currently being examined.

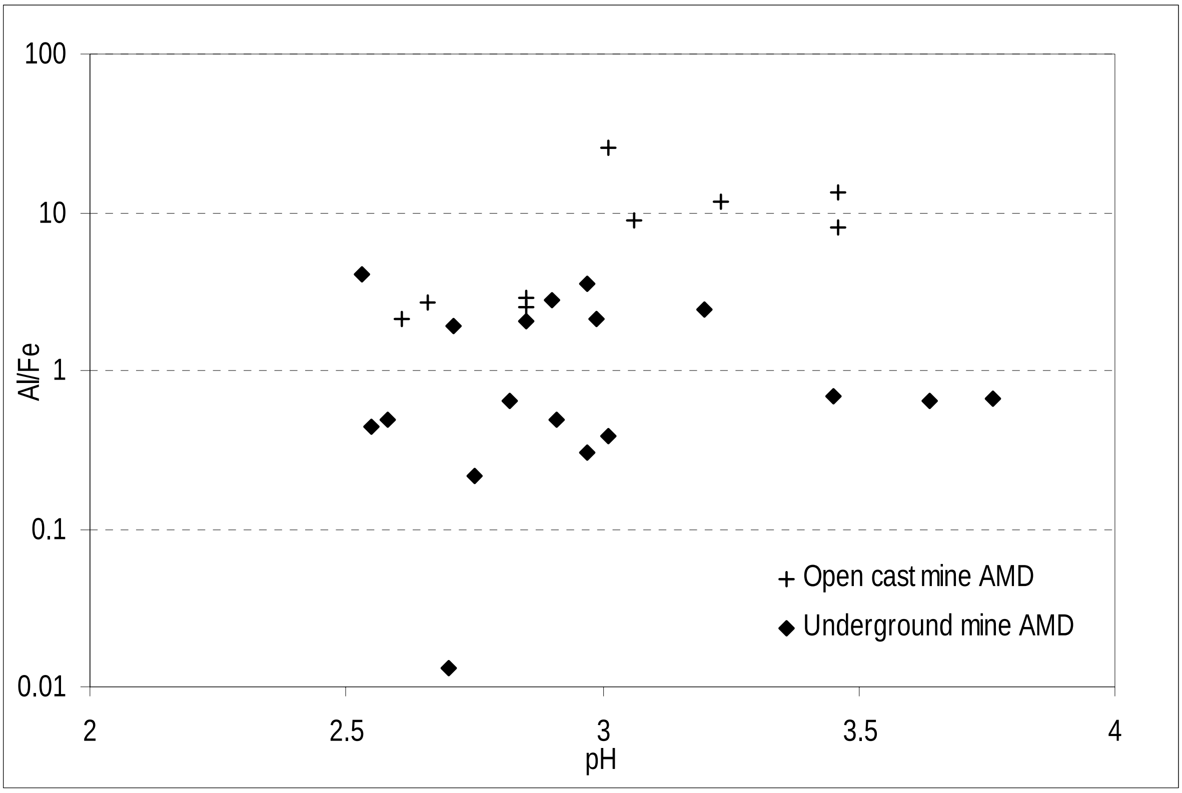

Figure 1. Ratio of Al:Fe vs. pH for AMD from mines in Brunner Coal Measures

Downstream from AMD sources, the concentrations of Fe and Al are often influenced by secondary minerals. Concentrations of Al in West Coast streams affected by AMD are controlled by alunite, gibbsite or bohemite, and possibly jurbanite (Figure 2).

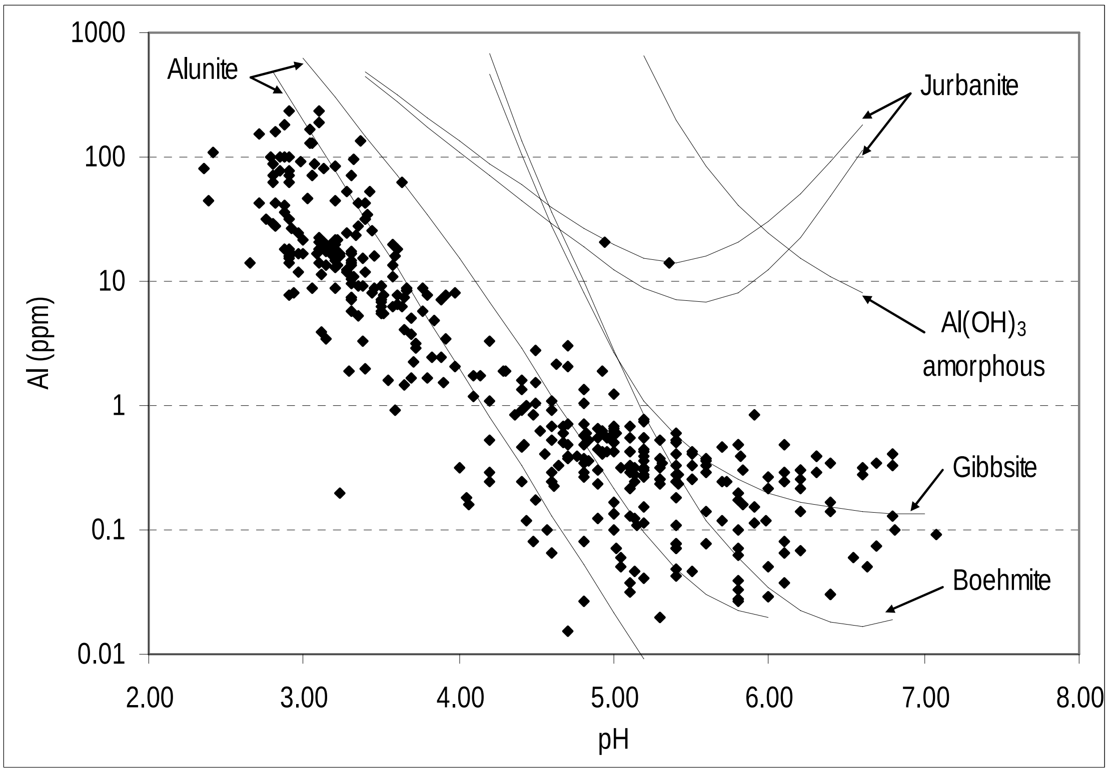

Figure 2. Minerals that control Al concentration in AMD sources and downstream environments. Multiple solubility curves are shown for Alunite and Jurbanite reflecting various possible concentrations of K and SO_4.

Summary and Future Work

Acid mine drainage is one of the most important environmental concerns for the mining industry. AMD related environmental data for the West Coast and Southland regions have been collated into a GIS database. Data types include rock geochemical data, water chemistry data and macro-invertebrate data. Information derived from this database combined with current collaborative research by CRL Energy, Landcare Research, University of Canterbury and Otago University is being used to produce a Framework to assist mine planning in the West Coast and Southland areas.

Future geochemical research includes identification of risks to water quality in the West Coast and Southland regions. This is currently being achieved by examination of controls on Arsenic and other trace element concentrations downstream of historic gold mining areas. In addition, factors that influence the composition of Brunner Coal Measures AMD are being assessed and controls on downstream concentrations of important parameters are being identified.

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