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Development of a textural index for the prediction of acid rock drainage

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ABSTRACT

The acid rock drainage index (ARDI) was developed to predict acid formation based on intact rock texture. Five textural parameters which have direct control on acid formation are evaluated. The ARDI forms part of the geochemistry–mineralogy–texture (GMT) approach to undertaking acid rock drainage (ARD) predictive tests. This staged-approach involves parallel use of geochemical, mineralogical and textural analyses. Sample screening is performed at stage-one, and a general classification given. Stage-two involves the use of routine geochemical tests in order to cross-check stage-one results, and also to quantify the acid forming/neutralising potential. Stage-three uses advanced geochemical tests and microanalytical tools to cross-check any ambiguous results from the previous stages, and for detailed characterisation of acid forming sulphide phases.

Samples were obtained from two mine sites in Queensland, Australia, from which seventeen mesotextural groups were identified (A–Q). The ARDI identified mesotextural groups J (quartz–pyrite) and H (quartz–arsenopyrite–pyrite) as extremely acid forming. Routinely used geochemical classifications also identified these as the most acid forming groups. Four mesotextural groups (K–O) were classified as having acid neutralising capacity after full GMT classification. The remainder of mesotextural groups were classified as not acid forming. Mesotextural groups G (quartz–galena–sphalerite), H and J only require kinetic testing to resolve the lag-time to, and longevity of acid formation, and to measure the concentration of potentially deleterious elements released. The ARDI was not able to confidently discern between samples with the capacity to neutralise acid, and those which are not acid forming. Therefore, further refinement of the ARDI is required. However, in its current form the ARDI is suitable for mineral deposits with low-carbonate contents. This paper demonstrates its use as part of stage-one of the GMT approach at both operational and abandoned mine sites to screen and classify acid forming potential.

1. Introduction

Undertaking effective environmental ore characterisation at the pre-feasibility/feasibility stage is essential for both efficient mine operations, and reducing the environmental impacts post-closure. Environmental parameters requiring characterisation include the propensity of a rock unit to form acid, deportment of deleterious elements, and emission of toxic dusts as a result of blasting. This paper focuses mainly on the prior, and presents a simple, yet effective technique to texturally characterise drill core and/or waste rock, and predict the likelihood of acid rock drainage (ARD) formation, as a complimentary new tool for use in ARD predictive studies.

International practice of predicting ARD broadly evolved into the wheel approach (Morin and Hutt, 1998) whereby laboratory, field-based and whole-rock geochemical assessments are recommended alongside mineralogical evaluations. Examples of the application of these tests are given in Blowes and Jambor (1990), Downing and Giroux (1993), Downing and Madeisky (1997), White et al. (1999), Paktunc (1999), Skousen et al. (2002), Smart et al. (2004), Stewart (2005), Weber et al. (2005a,b, 2006), Lapakko et al. (2006), Goodall (2008), Ardau et al. (2009), Lapakko and Bernt (2009) and Lindsay et al. (2009). Limitations of tests used in this approach were outlined in Dobos (2000). Procedures subsequently developed included the AMIRA P387A Handbook (2002) which addressed these limitations by providing more systematic guidelines, and by making use of advanced geochemical tests.

Most recently, the GARD Guide (2009) was published in which further improved guidelines for ARD prediction and characterisation are given (Verburg et al., 2009; GARD Guide, 2009). However, textural analyses in their own right are largely absent from most test work programmes. Instead, texture is used as a qualitative descriptor as part of mineralogical assessments, despite the direct influence of texture on acid formation, particularly in the waste

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rock environment (Plumlee and Nash, 1995; Mills and Robertson, 1998). Texture in the context of ARD must be clearly defined (or redefined). Such a definition should include measurement of sulphide and primary neutralising mineral contents, and an evaluation of the mineral associations of acid forming phases. Consideration should also be given to the reactivity of the acid forming phases, and their specific surface areas. Textural characterisation studies have to date focussed on micro-scale evaluations (Blowes and Jambor, 1990; Shaw et al., 1998; Gunsinger et al., 2006; Diehl et al., 2007). Few studies give detailed consideration to the mesotexture of acid forming phases and its control on acid formation. Therefore, application of the geometallurgical definition of texture is of use, as parameters such as mineral association, size and shape are all evaluated over a variety of scales (Bonnici et al., 2009).

Based on a review of current practices, a more up-to-date predictive approach is required. It must include the systematic and integrated use of geochemical, mineralogical and textural tests, and use geometallurgical tools where possible. This paper introduces the staged GMT (geochemistry-mineralogy-texture) approach as a means of addressing this, and includes the use of a novel textural evaluation scheme, the ARD Index (ARDI). Samples used in this study were obtained an operational iron-oxide copper gold (IOCG) mine, and from waste rock piles at an abandoned lode-gold mine, both located in Queensland, Australia. The geology, and stages of the mine life cycle differ between the two sites, allowing for critical assessment of both the GMT approach and ARDI.

2. Materials and methods

2.1. The geochemistry–mineralogy–texture (GMT) approach

The GMT approach is shown in Fig. 1 and comprises three stages of tests, two of which requiring parallel geochemical, mineralogical and textural analyses. With each stage analytical sophistication increases, and the number of samples analysed decreases. Therefore, after stage-one testing, the largest possible number of samples have been screened and given a crude acid forming potential classification. Stage-one tests were selected based on several factors. These included the relative ease and lower cost of undertaking these relative to those at stage-two, and the ability to obtain necessary data from other test work programmes (e.g. total sulphur values from assay as performed for geological/metallurgical studies). Only samples classified as not acid forming (NAF) (e.g. sulphides absent, neutral paste pH and an ARDI value of 0–10) are considered adequately classified and do not require further GMT testing. Acid forming samples require all stage-two tests to check the accuracy of stage-one, and to obtain values for the acid forming/neutralising potential. At the end of stage-two, samples confirmed as acid forming can be taken forward to stage-three if detailed microtextural and mineralogical analyses are required (e.g. for deleterious element deportment studies). Advanced geochemical tests are recommended (but not mandatory) to check the accuracy of stage-two results, with advanced net acid generating (NAG) tests used for acid forming samples, and the acid-buffering characteristic curve (ABCC) test for neutralising samples. After GMT analyses, samples can be appropriately selected for kinetic testing. The GMT approach is discussed here in the context of the two sites studied in this paper.

2.2. The acid rock drainage index (ARDI)

The ARDI evaluates acid forming sulphide minerals individually by five parameters (A–E) on both meso- and micro-scales. Parameters were specifically chosen based on their direct influence on acid formation. Categories A–C are ranked from 0–10, and categories D and E ranked from −5 to 10. Assessment by all parameters must be undertaken if acid forming sulphides are identified, or else the ARDI value is void. Meso-scale evaluations are performed on hand specimen samples, and micro-scale on petrographic thin sections. Cartoon examples of scorings are given in Fig. 2.

Prior to undertaking the ARDI, all intact rock samples selected for indexing are examined to identify the end-members of each parameter, making it site specific. This allows for the criteria of each score to be defined. Only iron-sulphides are assessed by the ARDI. Sulphides such as galena and sphalerite are not directly

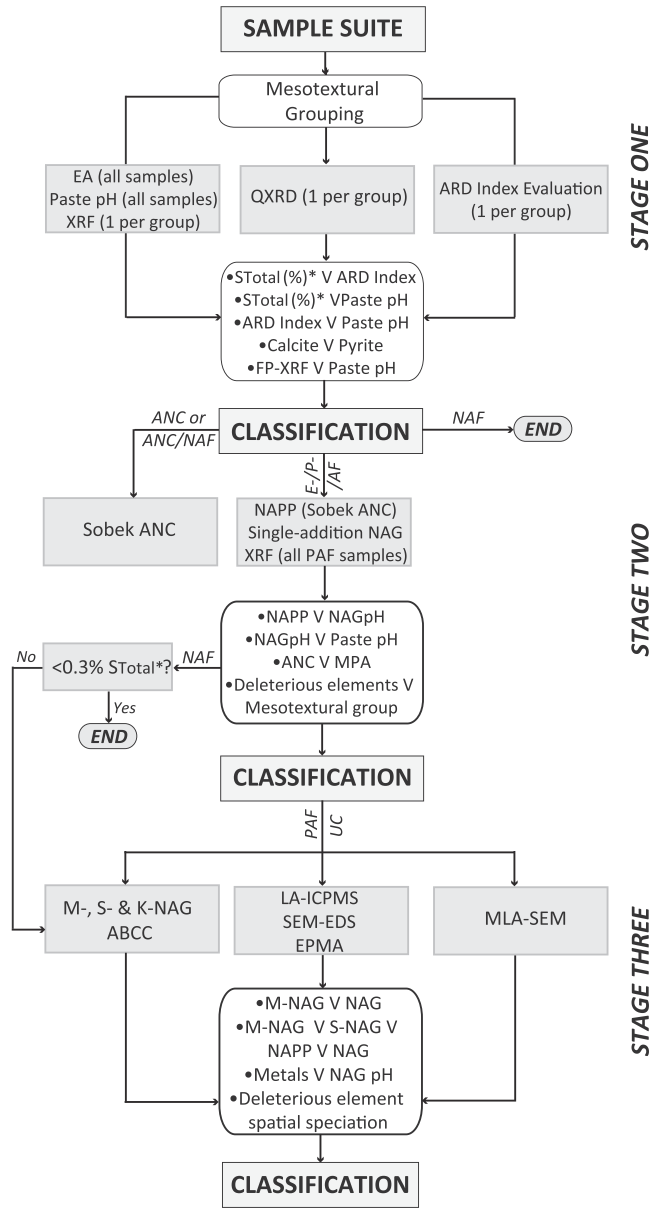

Fig. 1. The GMT approach with tests/analysis shown in rectangular boxes and evaluations shown in round cornered boxes. (EA – elemental microanalysis; (FP)XRF – (field portable) X-ray florescence; QXRD – quantitative X-ray diffraction; NAPP – net acid producing potential; ANC – acid neutralising capacity; NAG – net acid generation; MPA – maximum potential acidity; M-S – and K-NAG – multi-, sequential and kinetic-NAG; LA-ICP-MS – laser-ablation inductively coupled plasma mass spectrometry; SEM–EDS – scanning electron microscopy–energy dispersing spectrometry; EPMA – electron probe microanalysis; MLA–SEM – mineral liberation analyser–scanning electron microscopy; EAF – extremely acid forming, AF – acid forming, PAF – potentially acid forming, NAF – not acid forming, ANC – acid neutralising capacity) $^{*}S_{Sulphide}$ is preferred, however S_{Total} can also be used.