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The use of QEMSCAN and diagnostic leaching in the characterisation of visible gold in complex ores

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Abstract

Ore characterisation is an integral part of mineral processing especially in the gold mining industry where the use of an optimised process can mean the difference between economic and uneconomic ventures. In this study a method has been proposed using a combination of automated image analysis in the form of QEMSCAN and bulk chemical techniques in the form of diagnostic leaching. These methods can be used to characterise the 'visible' gold occurrences in complex gold ores as a precursor to more in depth analysis and identification of 'invisible' gold by microbeam analysis. It has been shown that by using this combined method it is possible to accurately identify both the distribution and associations of gold by QEMSCAN, with the results of diagnostic leaching used to verify this data and ensure a representative sample had been selected.

Keywords: Ore mineralogy; Gold ores; Liberation analysis

1. Introduction

The resurgence of exploration in the gold mining industry fuelled by a stronger gold price and growing need to extend ore reserves has placed renewed emphasis on the characterisation of ores from both green field discoveries and existing ore bodies. The importance of accurate ore characterisation is further highlighted by the dwindling number of easily processed oxide ore deposits and increasing number of low grade complex sulphide deposits being discovered and mined.

The complex nature and low grade of ore in an increasing number of new projects means that the traditional characterisation methods of cyanide amenability and gold particle liberation size cannot adequately explain the expected behaviour of an ore. These traditional methods are well suited to the determination of 'visible' gold, which is present as discreet particles of greater than 0.1 μm diameter (Henley, 1992). However, they are not useful in the determination of so called 'invisible' gold, which has been defined by Chryssoulis and Cabri (1990) as either solid solution or colloidal gold in the size range of 0.1 μm to. 001 μm. They also give only limited information on the mineral associations of gold and its distribution, which can be vital in establishing the most efficient processing route for an ore.

An accurate ore characterisation is essential in determining how an ore will behave in a traditional recovery circuit and whether it is free milling or refractory. A complete characterisation should identify the gold bearing minerals, show the fraction of gold in each and indicate how gold is associated with the minerals. With this information it is possible to determine the amenability of an ore to different processing options.

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Identification of mineralogy and 'visible' gold is traditionally performed by optical microscopy but the trend towards the use of automated imaging techniques is increasing. These techniques allow information about the mineral assemblages to be obtained at a much faster rate than traditional optical microscopy and hence increase the efficiency and decrease the cost of the process. A number of different automated imaging techniques have been proposed including automated optical image analysis (Oosthuyzen, 1985), automated electron microprobe (Jones and Cheung, 1988) and automated scanning electron microscopy (Gottlieb et al., 2000). Of these systems the automated SEM has gained the widest popularity with a number of different systems available commercially (Weller et al., 1998). The QEMSCAN system, previously known as QEM*SEM, is one such commercial technique that has been developed by CSIRO Minerals in Australia (Butcher et al., 2000).

The most sensitive analytical techniques available for the detection of gold and other trace elements in minerals are microbeam techniques. These methods can give sensitivities down to the low ppm and even low ppb range, can detect nanometre size micro inclusions and effectively identify 'invisible' gold. Some of the more common microbeam techniques include Electron probe microanalysis (EPMA), secondary ionisation mass spectrometry (SIMS), proton induced X-ray emission (micro-PIXE), synchrotron XRF, high resolution transmission electron microscope (HRTEM) and Mossbauer spectroscopy.

In this study the use of automated image analysis (QEMSCAN) for identification of mineral associations and visible gold occurrences has been used in conjunction with the bulk chemical method of diagnostic leaching as a pre-cursor to more sensitive microbeam techniques for determination of 'invisible' gold. By using this approach it was possible to get a comprehensive overview of the associations and distribution of 'visible' gold while identifying particles of interest for microbeam analysis whilst minimising the use of these time consuming and costly techniques.

By using a bulk chemical technique such as diagnostic leaching to compliment automated image and microbeam analysis, it was possible to ensure that representative results were achieved for each sample. Henley (1992) highlights the lack of representivity of polished sections as a major drawback of automated image analysis and microbeam techniques. This non-representivity arises from the low abundance of gold and gold minerals typically expected in most ores and becomes more pronounced as the particle size of gold increases. The work of Jones and Cheung (1988) showed that for a sample a gold concentration of 1 ppm and a gold grain size of 1 μm, only two polished sections were required for a representative sample but if the gold grain size was 100 μm, then 20,000 polished sections would be required. The use of a bulk chemical technique allows the broad distribution of gold in ore minerals to be established and compared to results from automated image analysis and microbeam techniques. In the case of diagnostic leaching this is achieved by the sequential acid digestion of a predetermined representative sample mass of an ore to show the proportion of gold associated with various mineral groups.

2. Methodology

Characterisation of samples using a combination of QEMSCAN and diagnostic leaching in preparation for microbeam analysis was done by determining first the ore mineralogy, gold grain size and liberation characteristics using QEMSCAN and X-ray diffraction, and then using this mineralogical information to tailor the diagnostic leaching method to optimise efficiency. The purpose of this study was to show the effectiveness of using QEMSCAN with diagnostic leaching for identification of appropriate grains for more in depth microbeam analysis.

2.1. Quantitative evaluation of mineralogy by scanning electron microscopy (QEMSCAN)

Automated image analysis for the identification of 'visible' gold associations was performed using the QEMSCAN system.

The QEMSCAN system is the third generation of automated mineral analysis systems that began with the QEMSEM at CSIRO 20 years ago (Butcher et al., 2000). It has now become a successful commercial instrument with 19 instruments in operation around the world at companies such as Rio Tinto, BHP Billiton, Phelps Dodge, Falconbridge and Anglo Platinum (Pirrie et al., 2004).

The system is based on a LEO 440/145 or Zeiss Evo 50 scanning electron microscope fitted with up to four light element X-ray detectors and pulse processor technology. It operates in a PC windows based environment, which allows for both online and offline interpretation of data (Butcher et al., 2000).

Back Scattered Electrons (BSE) and Energy Dispersive (EDS) X-ray spectra are used to create digital mineral images with mineral identification occurring online. Low-count EDS spectra are used preferentially to BSE brightness allowing minerals to be accurately identified by chemical composition. Individual minerals or groups of similar composition are identified by comparison to a comprehensive mineral database incorporated into the QEMSCAN software. The whole package allows for the identification of most ore and rock forming minerals in 10 milliseconds (Pirrie et al., 2004). A recent summary