

# ELEMENT FRACTIONATION AND MINERAL HOSTS IN THE REGOLITH

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## INTRODUCTION

There are two fundamental questions in regolith geochemistry of importance to geochemical exploration:

- How does an element move through the regolith (i.e. what are the processes and controls on element mobility and immobility)?
- Where does an element reside in the regolith (i.e. what are the mineral hosts in different parts of the regolith)?

Answers to the first question provide us with vectors towards mineralisation. Answers to the second tell us what to sample.

Fully understanding element-host mineral associations will provide breakthroughs in fine-tuning geochemical exploration techniques and improve exploration success, particularly in the regolith. This can be considered as “mineralogical exploration”, involving analysis and characterisation of specific mineral hosts. Targeting specific mineral hosts has the advantages of providing a consistent sampling medium, reducing geochemical “noise” and selecting for element concentrations directly related to mineralising processes or dispersion from mineralisation. There are three main approaches to establishing and utilising element-host mineral associations:

- Direct analysis of specific minerals (now largely possibly through low detection level microbeam analytical techniques);
- Selective extraction methods designed to release elements hosted or attached to specific minerals or phases;
- Numerical modelling of bulk geochemical data to reveal relationships of elements with particular minerals known or suspected to be present in ore or associated alteration.

During weathering of ore deposits, elements may follow a trail of hosts, being held or released from different minerals in different parts of the profile depending on chemical parameters. This can be considered a type of weathering-controlled fractionation process. The study described here examines the effects of this process up the weathering profile to the surface for a number of sites in the Cobar gold field of western NSW (Figure 1).



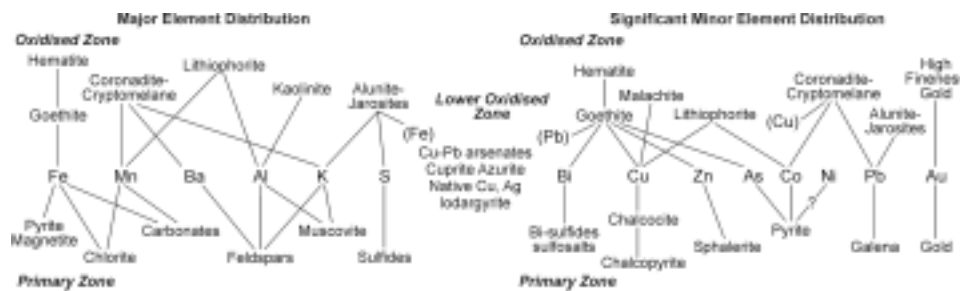
**Figure 1:** Location and geology of the Cobar gold field also showing known ore deposits and sites examined in this study. Insert shows the location of the Yarrowonga lag anomaly.

Polymetallic sulfide ores in the Cobar gold field have undergone prolonged weathering where they have been exposed at the surface or intersected by the water table. This has led to oxidation, chemical leaching and element dispersion, variable supergene enrichment and eventual mechanical dispersal of the weathering products across an evolving landscape. In addition to predominant Au and Cu the ores have associated Zn, Pb, Ag, Bi, As, Sb and W, which provide useful pathfinders for geochemical exploration.

## IN SITU PROFILE

Mineralogical and geochemical trends at the New Cobar Au-Cu deposit indicate a progressive change in mineral hosts from primary sulfide and specific secondary minerals (particularly Pb and Cu arsenates) in the lower part of the weathering profile to more generic Fe and Mn

oxides/oxyhydroxides towards the top (Figure 2). Goethite is an important host for Zn, Cu, As and to a lesser extent Pb, Bi and Sb. Hematite, where predominant, is an important host for Cu, Pb and Sb. Cryptomelane and alunite-jarosite group minerals are important hosts for Pb and As and lithiophorite for Co, Cu and Ni. Geochemical data on bulk samples from the lower part of the oxidised zone show very poor correlation of ore and pathfinder elements with Fe because they are hosted by a range of secondary minerals and not just the iron oxides/oxyhydroxides. Closer to the surface where most of the intermediate secondary minerals have been broken down, goethite and hematite are more important host minerals and a stronger correlation between these elements and Fe is evident in the bulk geochemical data.



**Figure 2:** Connectagrams showing the mineral host pathways for major and minor elements through the primary and oxidised zones at the New Cobar deposit.

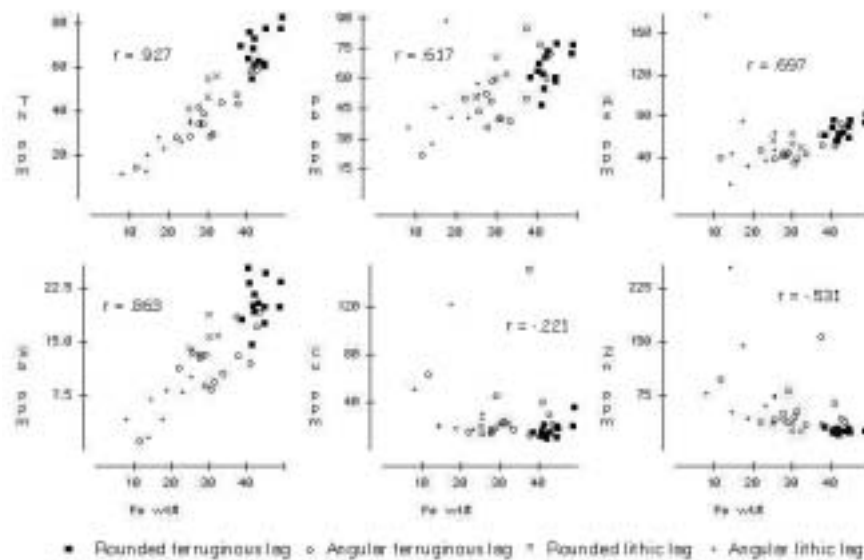
### NEAR SURFACE PROFILES

At the Wood Duck and Peak South prospects detailed mineralogical and geochemical investigation of the upper 20 m of the weathering profile indicates that there has been significant leaching of metals and sequestering of the remnant geochemical signal in goethite and hematite. Bulk samples from near-surface RAB drilling at the Wood Duck prospect contain less than 450 ppm Cu, 100 ppm Zn, 150 ppm Pb, 10 ppm As and generally less than 20 ppb Au (with up to 180 ppb in several samples near the very top of the profile). Primary mineralisation contains 1.75% Cu and 2.23 g/t Au, with trace Pb and Zn. Marked positive correlations between Cu and Fe in the near surface oxidised zone are consistent with concentration of Cu in abundant hematite within the profile. Lead and Zn contents are not significantly correlated with Fe. Similar sampling at the Peak South prospect indicates less than 100 ppm Cu, 250 ppm Zn, 100 ppm Pb, 300 ppm As and less than 100 ppb Au. Primary mineralisation here contains 4.24% Zn, 1.72 Pb, <0.02% Cu and 0.4 g/t Au. Goethite is the predominant Fe phase in the weathering profile and there is marked positive correlation of Zn and As with Fe. Copper is low in abundance and does not show significant correlation with Fe. There is no apparent correlation between Pb and Fe contents. Ferruginous lag immediately overlying the mineralisation at these sites contains variable mixtures of hematite and goethite and anomalous concentrations of Cu, As, Zn, and in some cases Au and Ag. These concentrations are significantly greater than in the underlying regolith. Sequential leaching analysis of these lag samples indicates that these elements are largely bound within the crystalline component of the iron oxide/oxyhydroxides.

### DISTRIBUTED LAG

A detailed study was made of lag from the Yarrowonga anomaly located down catchment of the Cobar gold field. Lag collected from 8 sites was subdivided into a number of different fractions including: a micro lag component (<120 µm), quartz lag, lithic lag, ferruginous lag and magnetic ferruginous lag. The last three categories were further subdivided into angular and rounded categories as an approximate means of separating the less reworked lag from the more reworked or transported. Geochemical trends in the lag indicate progressive increase in Fe content with rounding and presumably exposure and transport/reworking. Some other elements including As, Pb, Sb and Ba show a similar increase suggesting that these elements are being stably fixed in the more Fe-rich lag and their relative abundance increased as the non Fe oxide components of the lag are leached and removed. This represents a type of weathering fractionation of these particular trace elements driven by chemical leaching and mechanical reworking. A good marker for this process is the Th vs Fe fractionation trend (Figure 3). Quantitative XRD analysis of representative lag samples from the

Yarrowonga sites indicates that hematite (19-64 wt%), quartz (16-54 wt%) and muscovite (3-14 wt%) are the dominant mineral constituents. The magnetic lag contains up to 15 wt% maghemite, which is generally more abundant in the rounded fraction. Amorphous (poorly crystalline) components comprise 5-17 wt% and lesser kaolinite up to 6.5 wt%. Goethite comprises less than 2 wt% in this lag. There is a strong correlation between increasing Fe content and hematite abundance, which contrasts with the pattern for lag at the Wood Duck and Peak South sites. The abundance of maghemite is not significantly correlated with Fe content. Sequential extractions on the hematite-rich lag indicate that most of the trace elements of interest are strongly bound in the crystalline phases with virtually none in weakly adsorbed sites.



**Figure 3:** Bivariate plots of Fe versus pathfinder elements for lag samples from the Yarrowonga area. Each lag type has been subdivided into angular and rounded variants ( $r$  = correlation coefficient). Geochemical analysis was by INAA and ICP OES.

## CONCLUSIONS

To understand the behaviour of pathfinder elements in intensely weathered terrains it is important to identify their host minerals and understand how geochemical dispersion and weathering fractionation have affected the development of these. The story can be complex. For example, in the Cobar gold field, Pb and As within deposit profiles show limited chemical mobility, but once fixed in goethite/hematite near surface become mechanically widely dispersed. The Cu and Zn signature can be broad around the deposit but become progressively leached towards the top of the profile, where the metals are strongly correlated with Fe due to association with goethite and hematite. Prolonged surface exposure of ferruginous materials leads to progressive conversion to hematite±maghemite, increase in overall Fe content and retention and relative concentration of Pb, As, Sb and Ba. This represents the end stages of a weathering fractionation of trace elements driven by chemical leaching and mechanical reworking. The process is indicated by a marked Th vs Fe fractionation trend. Interpretation of lag geochemistry should take into account the tendency for As, Pb and Sb in particular to be relatively concentrated in the ferruginous component during surface exposure and transport. The relative enrichment of Th in the more hematite-rich, transported lag may provide a means for mapping out areas dominated by this material using detailed analysis of the Th channel in radiometric imagery.

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