

MINERALOGICAL EXPLORATION: USING ELEMENT-HOST MINERAL ASSOCIATIONS IN THE SEARCH FOR ORE

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The fact that ore deposits (economic concentrations of valuable elements) have characteristic mineralogical expressions has been recognised since the time of the 'ancients' and Agricola (Figure 1). With the advent of chemistry as a science, and the application of elemental analysis to mineral exploration, this fundamental relationship between the elements and their naturally occurring chemical compounds (minerals) has commonly been overlooked or considered less significant.



Figure 1: Mineral exploration circa 1500 (from *De Re Metallica*, Georgius Agricola). A is 'black box and arm waving', B is mineralogical exploration. How far have we progressed?

Geochemical exploration has typically involved chemical analysis of non-selective bulk geological samples. This approach has been highly successful at locating many important ore deposits. However, it is a crude, first-pass approach in applying chemical principles to mineral exploration. Sampling and analysis of specific soil horizons, size fractions and regolith zones, as well as selective leach techniques, have all been used in an attempt to refine this approach by targeting elements hosted or attached to particular mineral phases. Mineralogical exploration, involving analysis and characterisation of specific mineral hosts in rocks and regolith, has the potential to more finely target and more efficiently detect ore deposit expressions.

Mineralogical exploration applies knowledge of element-host mineral associations to detecting geochemical anomalies. This includes the use of specific host minerals in sampling and analysis, the use of mineral indicators related to mineralisation and the minor and trace element characterisation (chemical fingerprinting) of ore-related minerals. Targeting specific minerals has the advantages of providing a consistent medium, reducing geochemical noise and selecting for element concentrations directly related to mineralising processes.

There are three approaches to establishing and utilising element-host mineral associations (Figure 2):

1. The first approach involves direct analysis of specific minerals. This is now largely possible *in situ* for quite small mineral grains, through the development of modern microbeam techniques with sufficiently low detection limits (e.g. laser ablation ICP-MS, ion probe and new generation electron microprobe methods). It can also be achieved by using traditional or new sample separation methods combined with ultra-low-detection analytical techniques;

2. The second approach uses selective extraction methods designed to release elements hosted or attached to specific minerals or phases;
3. The third approach employs numerical treatment of bulk geochemical data to reveal relationships of elements with particular minerals known or suspected to be present in the ore or associated alteration halo.

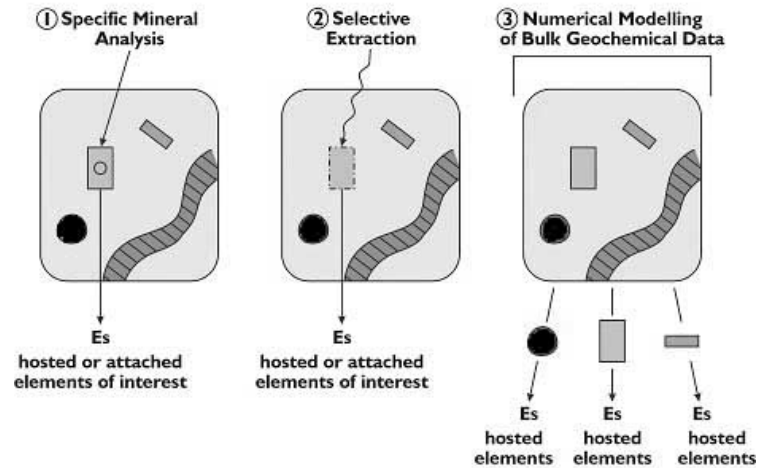


Figure 2: The three main approaches to detecting and using element-host mineral associations for mineralogical exploration.

These approaches can be applied to defining primary and secondary dispersion anomalies. Much is known about element partitioning into specific primary minerals but there is little understanding of controls in the secondary environment, particularly element dispersion processes, pathways and sequestering of elements into specific secondary minerals. More research is needed to improve our understanding of the secondary fate of elements derived from primary geochemical anomalies and mineralisation, as distinct from background sources. We may need a "Bowen's Reaction Series" style approach to understanding and predicting the behaviour of elements during weathering processes.

Several differing examples serve to illustrate the concept of mineralogical exploration:

1. Regolith carbonates (calcrete) form in the near-surface regolith profile in semi-arid regions and fix mobilised gold. Calcrete is easily identified, shows a strong association with gold and provides a consistent sampling medium. It has proved to be an important sampling medium in gold exploration (Figure 3);

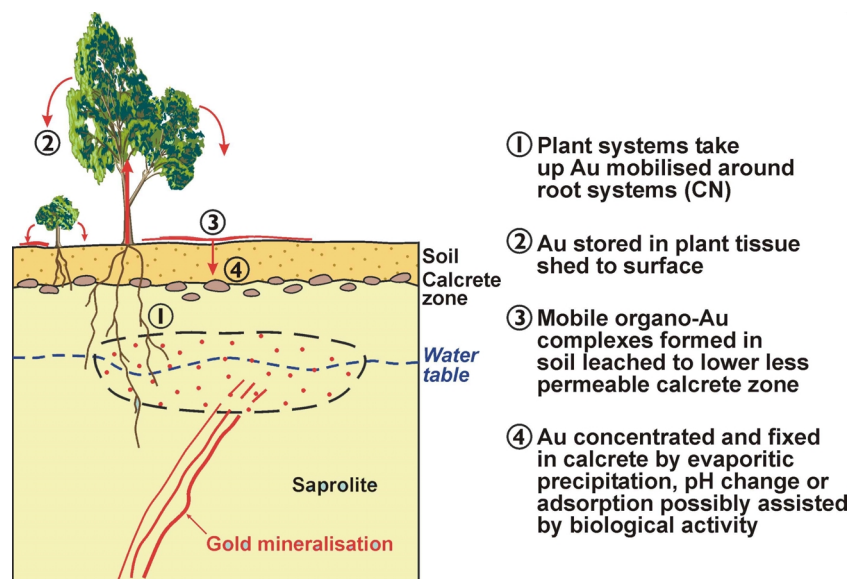


Figure 3: The calcrete-gold association (modified from Lintern & Butt 1998).

2. Certain resistate minerals, such as magnetite, which occur both as accessory and ore-related minerals can be 'fingerprinted' by their minor and trace element compositions. This provides a technique for detecting mineralisation-related magnetite dispersed as detrital grains (e.g. McQueen & Cross 1998).

For example, magnetites in the Paddys River catchment, ACT, are sufficiently distinctive in their minor element characteristics to allow skarn-derived magnetite to be identified in stream sediments (Figure 4).

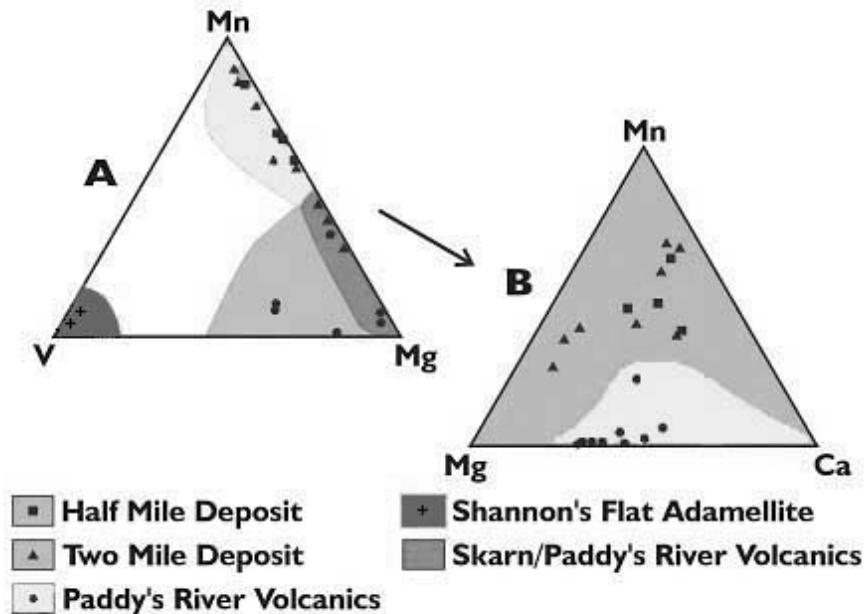


Figure 4: Minor element characteristics of magnetites from different rock types and magnetite skarn deposits in the Paddys River area of the ACT. Mn-Mg-V-Ca variations are sufficient to discriminate between the magnetites in the Paddys River catchment.

Hydrothermal magnetite related to mineralisation at the Goonumbla porphyry Cu-Au system, North Parkes, NSW, shows distinctive minor element characteristics (Figure 5). Templates based on these minor element variations, combined with trace element features, have the potential for discriminating mineralised from unmineralised porphyry systems and for detecting magnetite dispersion trains related to porphyry Cu-Au deposits. Magnetite is a very easy mineral to sample in the regolith.

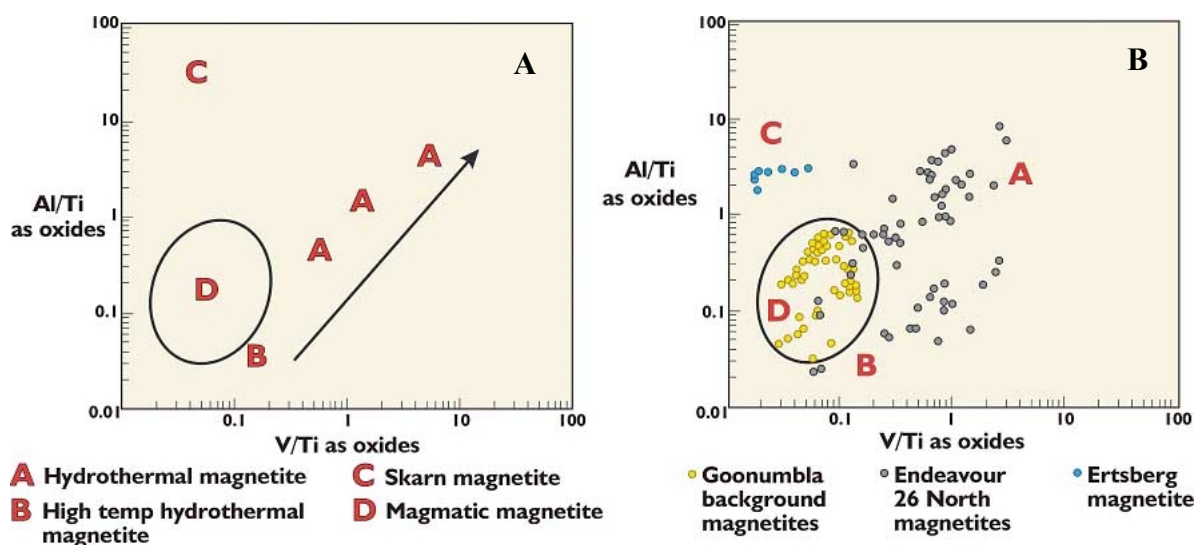


Figure 5: A. Typical minor element characteristics for porphyry-related magnetite types. B. Magnetite minor element plots for unmineralised porphyry (Goonumbla background) and Cu-Au mineralisation (Endeavour 26 North), Goonumbla porphyry system North Parkes, NSW.

Alteration patterns are developed around hydrothermal ore deposits and are reflected as cryptic patterns in the subsequently weathered rocks. In many cases it is difficult to detect the patterns visually or describe them in an objective or quantifiable way. These patterns have a fundamental mineralogical control that can be explored by special numerical analysis of the bulk geochemistry. General element ratios (GERs) are constructed such that minerals known to be present plot as specific nodes. Trends between these nodes indicate mineralogical variations related to alteration and superimposed weathering (Figures 6 and 7).

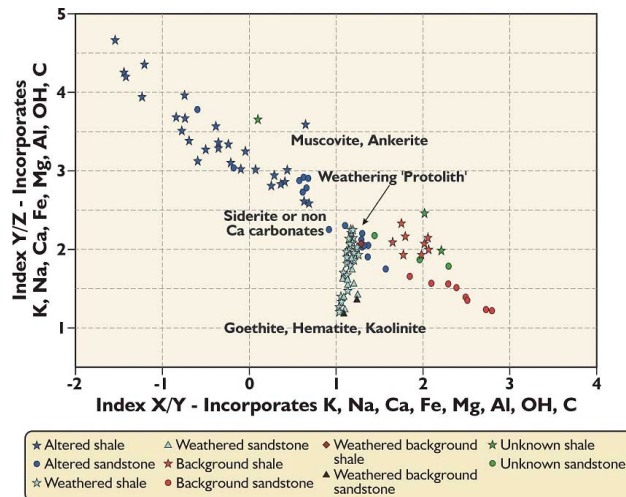


Figure 6: General element ratio plot for background, hydrothermally altered and weathered lithotypes from the Elura Zn-Pb-Ag deposit, Cobar NSW. In this case little of the characteristic siderite-dominated alteration signal seen in the unweathered, altered rocks is preserved in the weathered equivalents which, along with the weathered background rocks trend towards goethite-hematite-kaolinite.

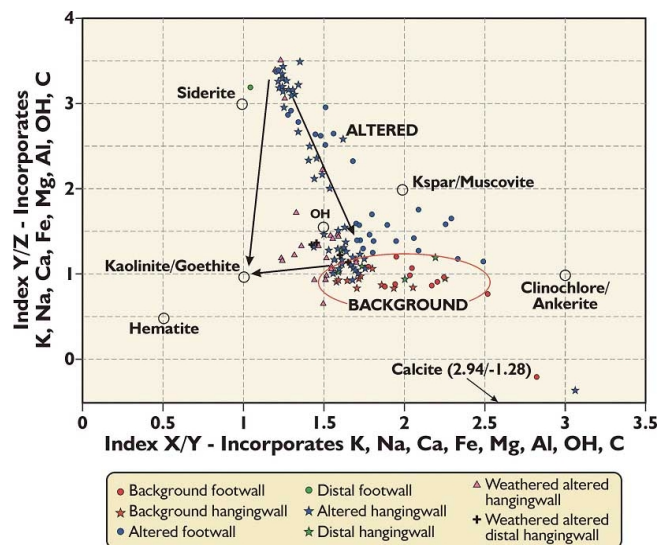


Figure 7: General element ratio plot for background, hydrothermally altered and weathered shale from the Century Zn-Pb-Ag deposit, Queensland. In this case some of the primary alteration signal in the unweathered, altered rocks is preserved in the weathered equivalents.

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