RATIO ANALYSIS OF BULK GEOCHEMICAL DATA: TRACKING ORE-RELATED CRYPTIC ALTERATION BY MODELLING MINERAL CHANGES

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Many economic base metal deposits are the product of metal sulphide precipitation from hydrothermal fluids. The chemical reactions between these mineralising fluids and the rocks hosting the deposits commonly produce 'haloes' of distinctive mineralogical and geochemical character, zoned about the deposits. The extent of the alteration depends on how extensive the fluid pathway is and the importance of diffusive processes but is generally much larger than the deposits themselves.

Exploration companies commonly rely on geochemistry to identify alteration haloes. However, examination of raw data or even simple ratio trends (e.g. empirical alteration indices) is prone to error due to closure effects and/or pre-existing background variation. Closure can be avoided by using ratios, or by utilising mass balance approaches based on fixing volume, mass or concentration changes between samples of parent and daughter lithologies. Using a parent-daughter approach is limiting because only pairs of samples can be compared at any one time and also because an unaltered equivalent must be produced for each sample examined in this way. Ratio methods are not restricted in this fashion and are more amenable to interrogation of large data sets. Furthermore, the ratio methods outlined below are readily applied to commercially derived lithogeochemical assays.

Pearce Element Ratios (PERs) are molar ratios formulated using a conserved element as the denominator. The ratioing of major elements removes dilution/concentration effects that occur during protolith formation and any later alteration events. For example, quartz dilution in felsic volcanics or turbiditic sediments can be removed to examine true K and Al concentrations, relative to the denominator element. The PER approach relies on the predictable major element variations that result from mineral changes, with slopes on PER diagrams being dependent on mineral stoichiometry. For example, orthoclase ($KAlSi_3O_8$) would plot with a slope of 1, and muscovite with a slope of 1/3 on a K/Ti versus Al/Ti PER diagram (Figure 1). By collapsing multiple minerals trends, the entire compos-itional range of unaltered samples can be accounted for on a single line (should this prove to be mathematically possible). Any changes to the initial composition (related to alteration events) can be monitored and quantified both numerically and graphically as variations from the line. In this way PERs can be used to filter out unwanted geochemical 'noise' and allow observation of alteration geochemistry associated with the ore-forming event. The intensity of mineral changes should increase with proximity to ore.

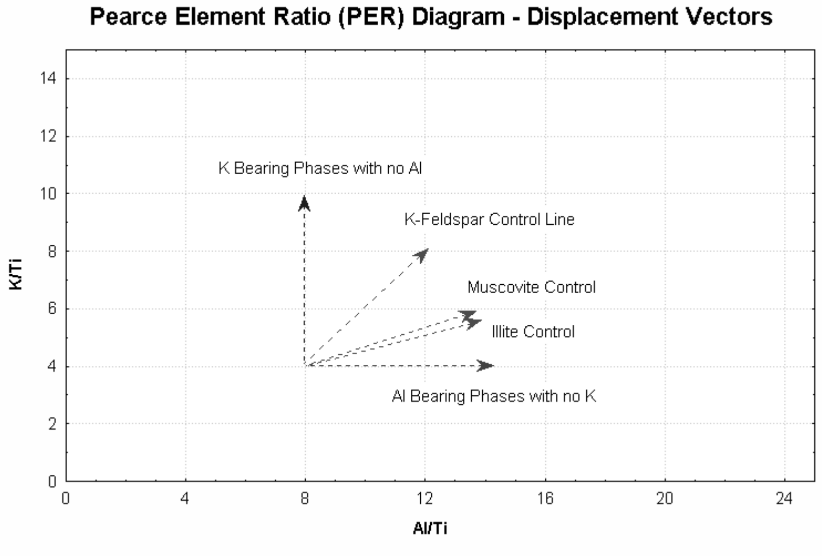

Figure 1: Molar K/Ti versus Al/Ti Pearce Element Ratio (PER) diagram. Samples composed of K-feldspar will plot along a line with a unit slope. If muscovite is added, the sample will plot between the K-feldspar and muscovite slopes, depending on the proportion of the two minerals.

In: Roach I.C. ed. 2002. *Regolith and Landscapes in Eastern Australia*, pp. 133-135. CRC LEME.

General Element Ratios (GERs) are molar ratios but, unlike PERs, do not use a conserved element. GERs rely on covariation of elements to pinpoint mineral controls on chemical variation and can be used in situations where no evidence of conserved elements exists. The denominator may be a single element, or a linear combination of elements. Because minerals commonly plot as points (nodes) on GER plots, different minerals can be plotted at different locations on the diagram. Samples will move towards a node with the greater the abundance of that mineral in the specimen. A tie line can be established between altered and background mineral suites and samples can then be quickly assessed for their exploration significance. An example GER diagram is shown in (Figure 2).

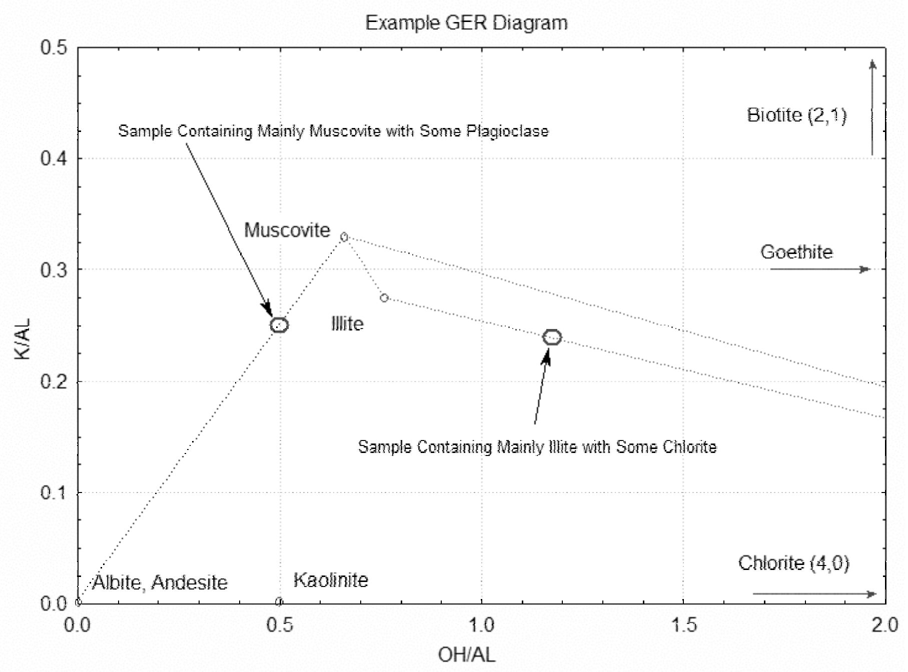

Figure 2: General Element Ratio Diagram, Molar K/Al versus OH/Al. Minerals plot as nodes (rather than vectors). Some example compositions are shown (as larger circles).

PER and GER methodologies have been applied to the Century and Elura orebodies (Figure 3). The Century orebody is located some 250 km northwest of Mount Isa in northwest Queensland. It is a large (118 Mt at 11.7% combined Zn and Pb; Waltho *et. al.* 1993) shale-hosted deposit and is developed within gently folded Proterozoic Lawn Hill Formation shales and siltstones. The Elura orebody is located 50 km north of Cobar, in mid-west New South Wales. It is a smaller Zn-Pb-Ag deposit (45 mt @ 8.5% Zn, 5.3% Pb, and 69 ppm Ag; Lorrigan *pers. comm.* 2002), hosted within Devonian aged siltstone-sandstone turbidites of the Cobar Basin. Both show visible iron carbonate and limited pyrite alteration, with evidence of more extensive elemental anomalies.

Cryptic alteration in the carbonate and phyllosilicate portions has been successfully identified at both deposits. This was achieved by careful, phased sampling of 'fresh-rock' material spatially associated with mineralisation and subsequent analysis using PER methodologies. Iron carbonate development and subtle potassic alteration are the dominant bulk alteration effects at both deposits. Various 'pathfinder' trace elements are associated with these mineral changes but the relative timing of trace and mineral changes is difficult to constrain. Elura potassic alteration and pathfinder abundances grade in intensity towards mineralisation, whereas carbonate changes are quantised. Century alteration is somewhat quantised but is far more extensive than that at Elura, due to the size of the mineralising system. In this situation, combined use of trace element pathfinders with PER signatures would be necessary to navigate through the large alteration halo towards ore.

GER diagrams were used to project weathering effects from a fresh-rock alteration tie line. At Elura, cryptic potassic alteration can be detected in certain weathered samples but weathering processes generally destroy major element alteration indicators. Many trace elements pathfinders are also lost during weathering. Such destruction is not as extensive at Century, for either major or trace elements. The difference in weathering effects at the two deposits suggests that different processes and/or different landscape evolution processes have occurred. Elura may have had multiple, possibly intense, weathering 'events' accompanied by preservation of the developed profiles. Weathering effects at Century seem to be more embryonic, possibly due to the stripping of weathered material coupled with less intense weathering conditions.

Figure 3. Location of Elura and Century Mines within Australia.

REFERENCES

WALTHO A.E., ALLNUTT S.L., & RADOJKOVIC A.M. 1993. Geology of the Century Zinc Deposit, Northwest Queensland. *Australian Institute of Mining and Metallurgy World Zinc 1993 Conference Proceedings*. 111-129.