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# The Regolith, Backgrounds, Anomalies and Partial Leaches

The landscape of much of Australia and most other continental cratons or tectonically active continental margins is characterised by a mix of deep weathering, extensive erosion and valley fill deposition that gives rise to a complex regolith environment containing elements of remnant old and younger superficial cover. Rocks of any age may occur as zones of deeply weathered saprolite exposed through, or lying beneath clay and silt to gravel-filled incised Tertiary and Quaternary river channels. These in turn may be covered by broad sheet wash areas of Recent wind or water transported soil or sediment.

In the arid zones of the "classic" older cratonic regions of Australia, Brazil or central and Saharan Africa and the mountainous Andean terrain, extensive but generally eroded outcrops of ferricrete, silcrete or calcrete duricrust may occur capping the landscape. The presence or absence of these is a function of climate, the extent of rock weathering and available sources of water, Fe, Si, Ca and other components in the rock units. In these regions there is active generation of new "crete" veneers forming

within the present drainage depressions where they cement weathered country rock or recent sands and gravels. These features are illustrated schematically in **Figure 1** (Anand & Paine, 2002). Geochemical sampling is therefore likely to result in collection of multi-age, multi-source, lithologically divergent transported sample media. Much care needs to be taken to systematically document field sites and the erosional level or depositional character of the immediate terrain or catchment sampled.

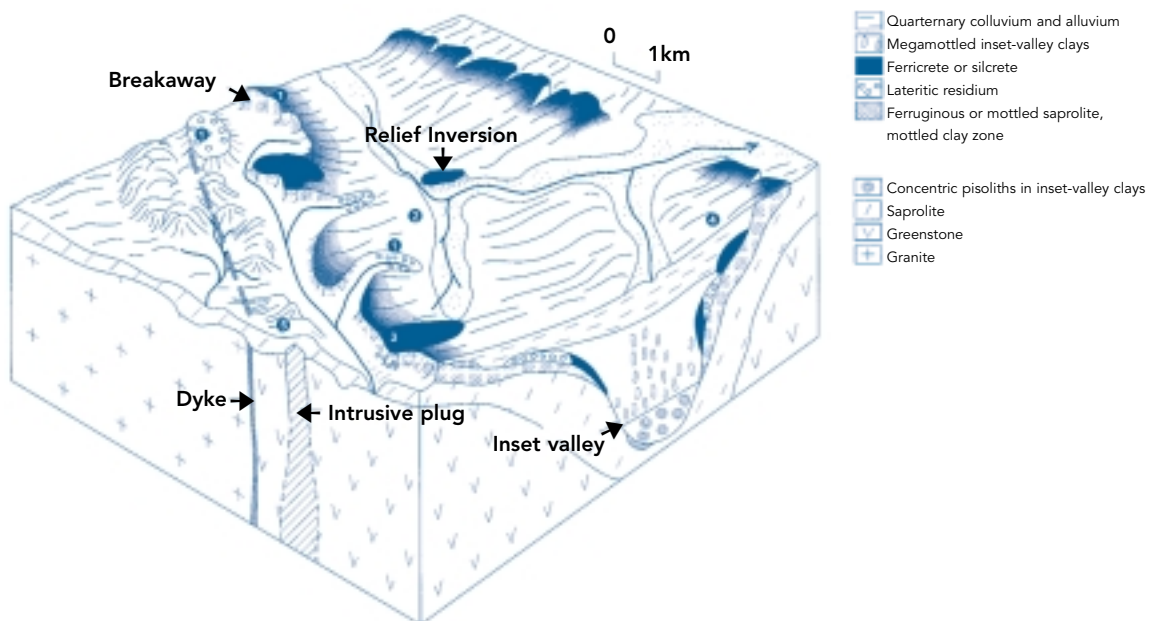


Figure 1 Schematic diagram of variable sample terrain that may be included in an exploration program.

This Newsletter outlines some of the ways in which a field setting and position of mineralisation in a terrain can interact with the geochemistry of our soil or stream samples and influence how we interpret analyses. It outlines geochemical and sampling strategies and highlights the use of multi-element partial and selective leach techniques that might be considered to undertake geochemical exploration in complex physical, pH, redox and saline terrains. Such an approach can assist in discrimination of variably leached bedrock geochemistry from weak ore related geochemical anomalism introduced into the soils through evaporative and other processes along restricted pathways.

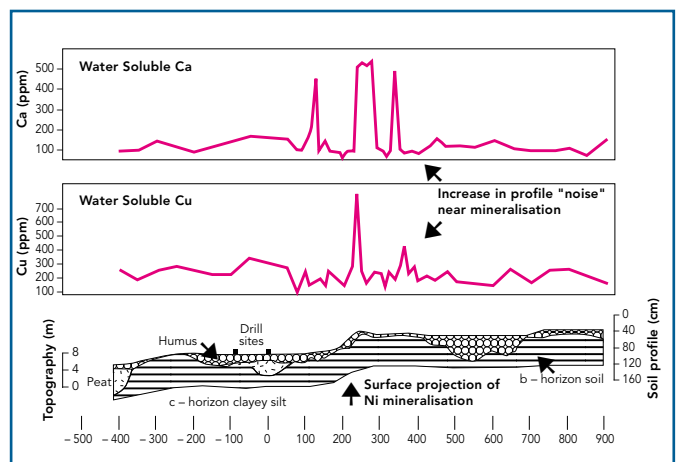
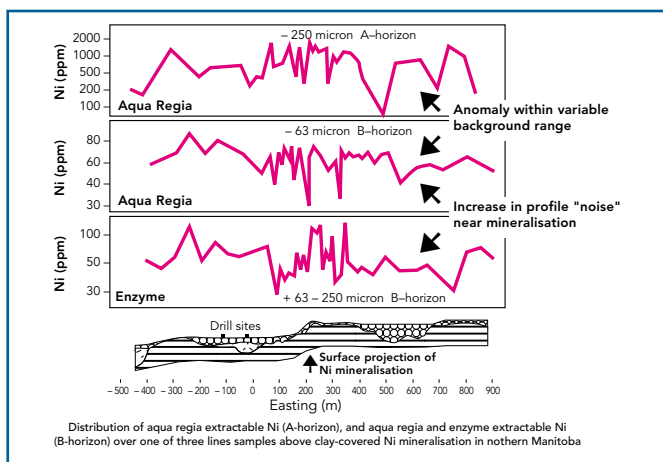
## Backgrounds, Anomalism and Geochemical Targets

When the mineralisation we seek is buried at some depth under younger cover rocks, we face a problem in that surface geochemical anomalism derived from it will be predominantly sourced through relatively narrow vertical joints, fractures and other pathways rather than be pervasive through the bulk of the surface material that is readily accessible for sampling. Sometimes distinctive geochemical signatures from these geochemically anomalous pathways might be detectable over a broad area due to the way in which mechanical and chemical dispersion processes have operated during the recent past. However, this is frequently not the case and a veneer of sheet wash, duricrust or soil can often hamper location of these discrete anomalous fracture sources and, in some instances, geochemical anomalies can appear disconnected from a source. Anomaly patterns in these circumstances are normally spiky and erratic in character and rarely produce the discrete "classical" (gaussian or log-normal) response patterns that we are familiar with from areas with exposed bedrock with outcropping mineralisation. We need to remodel the concept of what constitutes background and anomalism to interpret geochemical data from deeply weathered terrains or from areas where mineralisation lies at depth or is under younger cover.

Partial leach methods, because of their much lower detection limits can reliably measure background variation. This is seen in line profile data as changes in the noise base level along a line. We are so used to seeing flat backgrounds from total analytical methods that when presented with the real character of background populations seen in partial leach data we consider the analytical method faulty rather than acknowledging what the real world variation in natural background geochemistry is like. **Figures 2a & 2b** (Seneshen, 1999) illustrates profiles that are very typical of partial leach data. Three leaches are illustrated, water, enzyme leach and a "total leach" aqua regia.

What should be noted is the way in which the profile "noise" character differs from background to anomalism. Anomaly zones are typically much more noisy or "active" than background areas and this is related to sampling in the vicinity of geochemically anomalous pathways over the mineralisation. These are of course absent away from mineralisation.

A background level of an element may be considered to be a typical range of values found in a particular un-mineralised rock type in an area. A background for any given rock type will vary depending upon the degree of weathering, changes in geomorphic setting, local hydrology and climate in an area. An anomaly is created when a component of interest is added to a background from some external source. It follows from this that there is not necessarily any relationship (statistical or otherwise) between a background value and an anomalous value. We often assert that there is a relationship, and this "approximation" is generally reasonable where we have strong anomalies from exposed or shallowly buried mineralisation in areas of outcrop and where real background signatures are swamped by the signal from the mineralisation. This is definitely not true in areas of cover where geochemical responses are weak, response patterns are frequently highly erratic due to inconsistent fracture distribution and where it is often the presence or absence, in a qualitative sense, of key vector elements that gives the clue as to the presence of mineralisation.



**Figures 2a & 2b** Examples of leach profiles. Of particular note is "noise" characteristics of anomalous and background sections of profile.

The concept of "threshold" (the change from values we ignore to ones that we might follow up) should be abandoned. While it is a useful "concept" in areas with good outcrop and with limited weathering it becomes increasingly less useful with increase in depth of weathering or cover as the relationship between variable backgrounds and what constitutes anomalies changes, for example, in cases where anomalism is a qualitative rather than quantitative parameter.

In exploration geochemistry we should try to measure the anomalous component and not a (variable) background. In practice this can be a difficult task. Partial and selective leach methods such as **Regoleach** (ALS Chemex method **ME-MS08**) attempt to do this. Potentially they offer significantly more opportunity for detection of subtle anomalism from unexposed or blind mineralisation than total analytical methods. They do this by preferentially dissolving the more soluble or mobile components precipitated or adsorbed onto the surface of grains, the weathered rind about grains and within joints leaving much of the (variable) background matrix component largely untouched. Pulverising

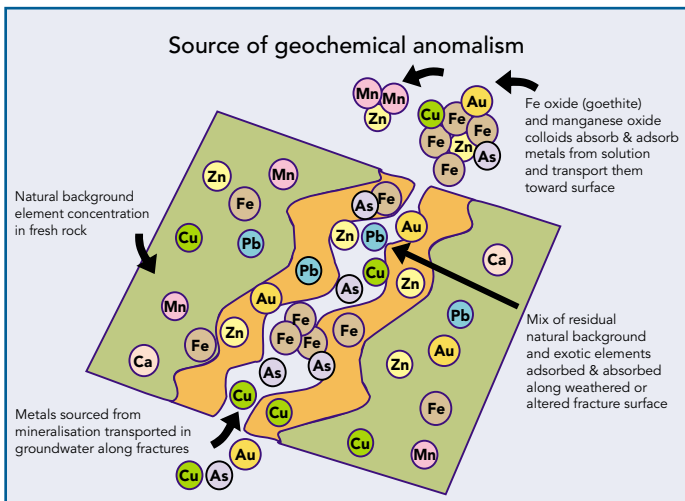
and analysing a whole sample using a total digestion will therefore mix and could "lose" a subtle anomaly signature, the objective of our analysis, in a variable background. Total analytical methods, where the material is pulverised, do not differentiate between variable background signatures and the introduced anomalous component. A conceptual model of where anomalism is likely to reside in a rock or soil is illustrated in **Figure 3**.

In variably weathered terrains with cover masking mineralisation, the geochemical signal from mineralisation is added to or "carried" by a variable and unknown background signature. The variation in the background geochemistry may be greater than that of the signal from the ore body we are seeking as illustrated in **Figure 4**.

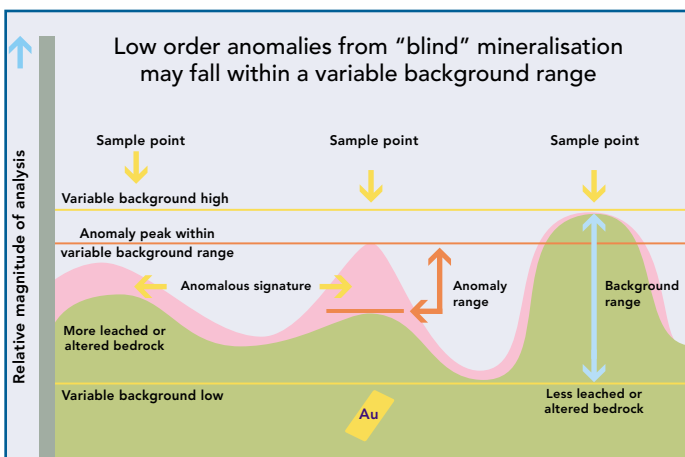
The geochemical signature we seek (from Figure 4) can be a small part of the total analytical value as shown in **Figure 5**.

## Partial and Selective Leaches

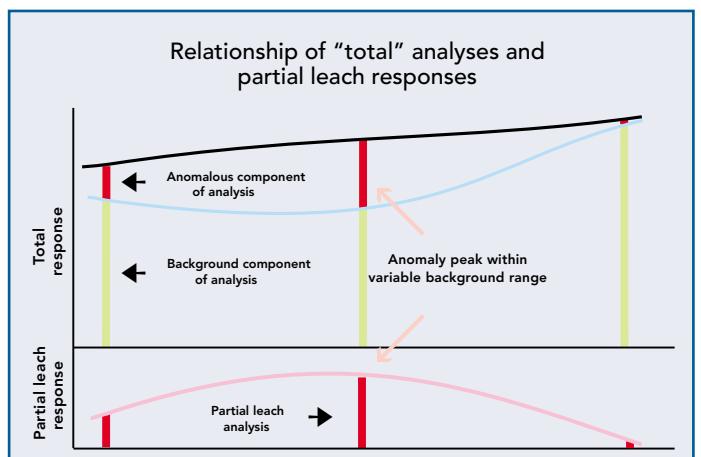
A significant drawback with total leach digestion methods is that they limit the use of analytical technologies such as ICP-MS, due to the high ionic solution strengths that result from the dissolution. This restricts lower detection limits to relatively high levels (~0.5ppm). By using selective or partial leaches on unmilled material, ionic solution strengths are much lower and ICP-MS can be used with detection limits lowered by up to 100 times or more (1-10ppb). It is this ability to measure very low levels of ore-related trace elements in transported or weathered overburden that allows us to "see" deeply buried or covered mineralisation. This attribute is unavailable to us in many instances using total analyses. The **Regoleach** process (ALS Chemex method **ME-MS08**), for example, has been optimised to exploit the advantages of very low detection levels available by ICP-MS yet still determine more abundant "major" components by ICP-AES.



**Figure 3** Source of geochemistry in a sample. We are really only interested in the anomalism from the joint or fracture zone.



**Figure 4** In variably weathered rocks where anomalism is confined to fracture and joint zones an anomaly signature may lie within the variable background range.



**Figure 5** Illustration of total and partial components of an analytical value.

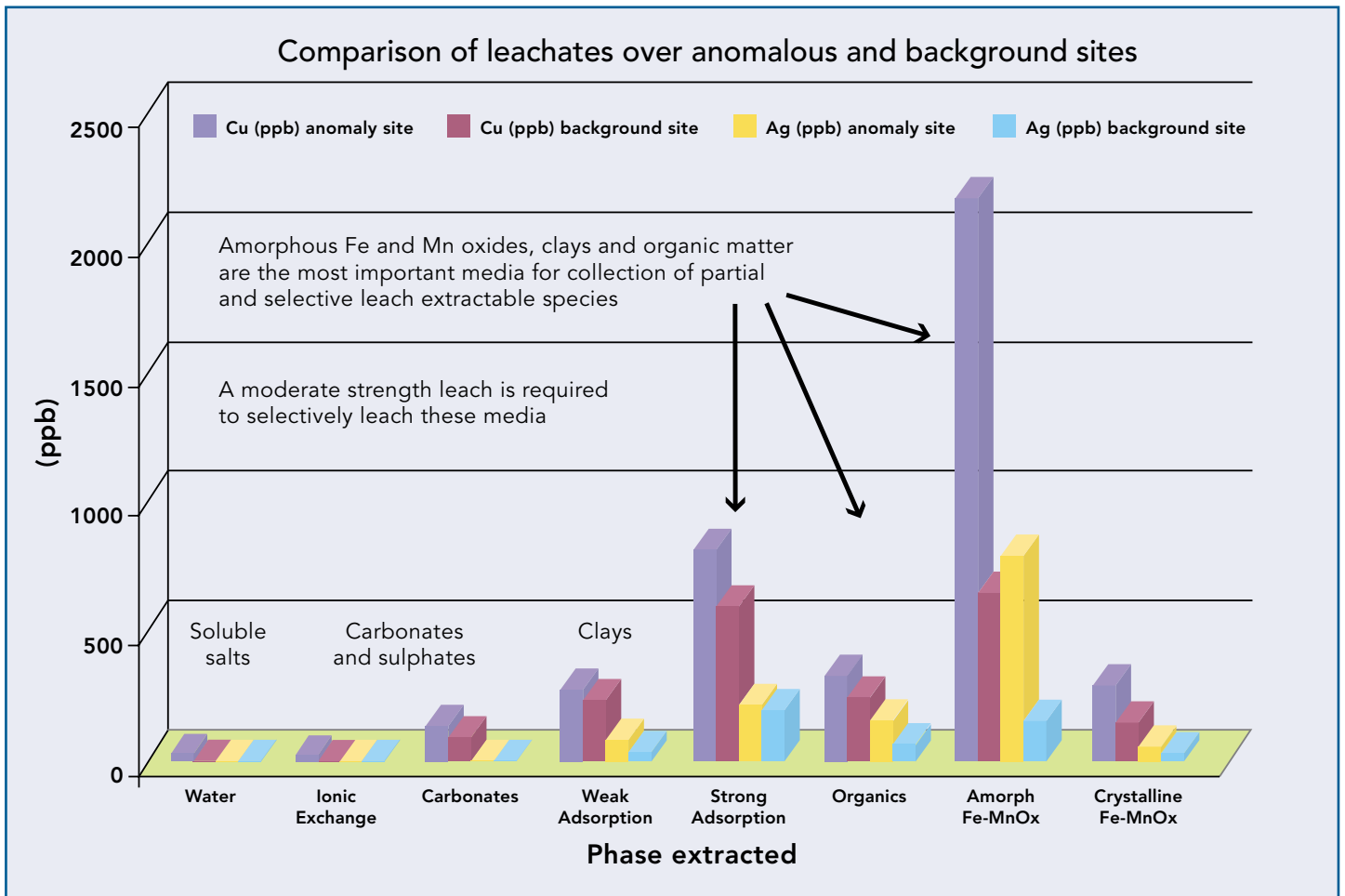


Figure 6 Relationship of host material and potential residency for anomalous geochemistry in superficial environments.

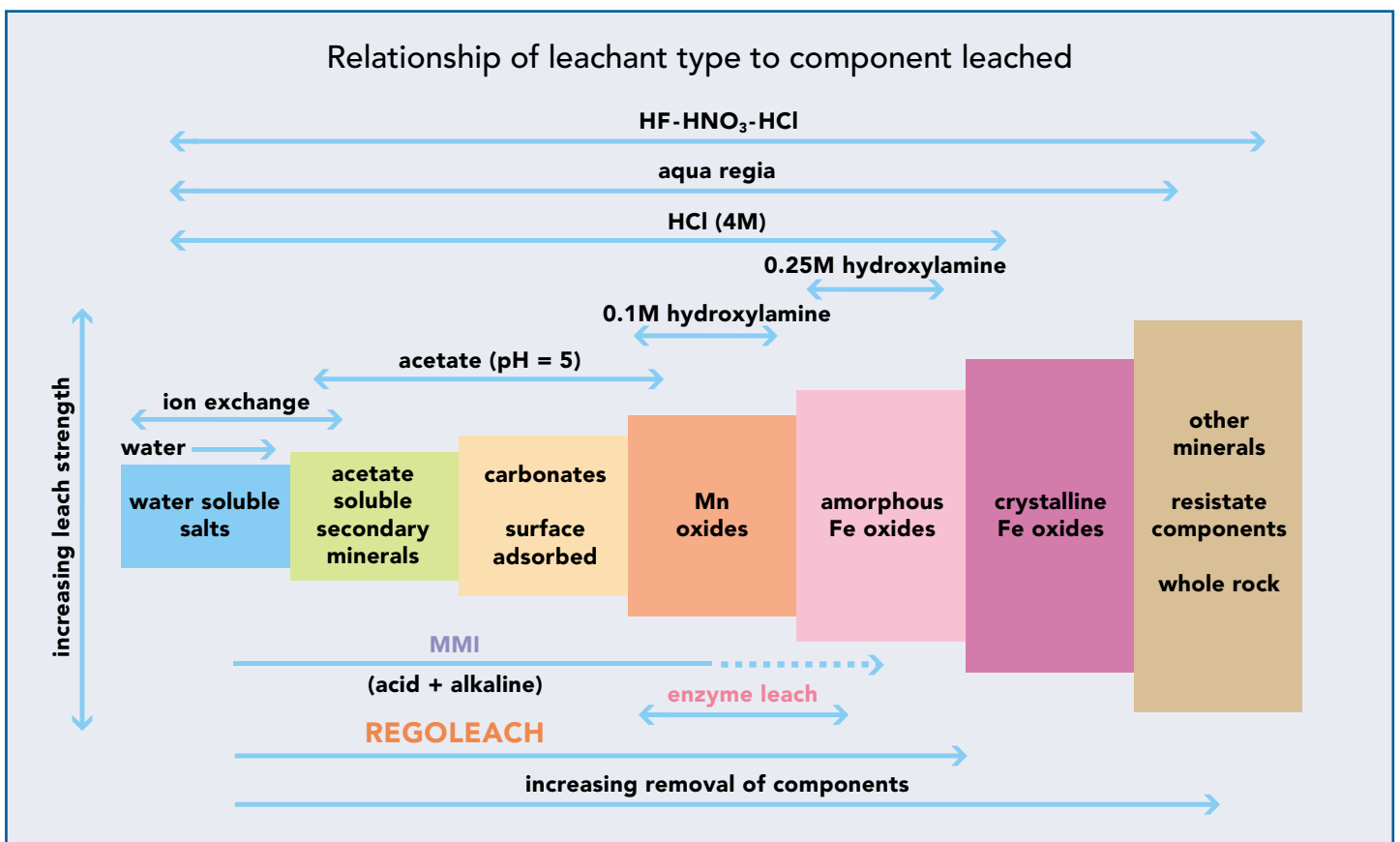


Figure 7 Relationship of leachant type and component leached in a sample. The Regoleach partial leach analytical procedure is designed to optimise analysis over a wide range of conditions (after Gray, 1998).

Depending on the local superficial environment an anomalous component can be associated with amorphous Fe or Mn oxides or their aggregated equivalent (eg. laterite, pisolite, gossan, etc), be partitioned into a carbonate or sulphate phase. Alternatively, it may be absorbed into clay or be complexed with some organic phase. Leaches, such as **Regoleach**, that remove the anomalous component from most of these probably best reflect the "total" anomalous component transported from an ore body at depth to the surface. They are also less susceptible to local superficial environment variations. We should therefore bias our sampling toward those components in the landscape, in particular the pathways that are the most likely host for elements of interest. We should then select leach methods that most appropriately exploit the "capture" potential of those sites to measure the weak mineralisation signatures anticipated, thereby separating them from variable background signatures. This is summarised in **Figures 6 and 7**.

Partial and selective leach methods work by dissolving the weakly bound ions (cations or anions) attached to or absorbed into the sample matrix (soil, weathered rock fragments) and crystallised in the sample matrix. Selective leaches are designed to only attack specific components within a sample. Some methods dissolve precipitated carbonates or other salts, while others attack Mn-oxides or amorphous Fe-oxides, or strip ions held in organic complexes. Partial leaches, which often have a low pH (acid), might attack all of these to some extent. The degree of dissolution depends to a large extent on the intensity of weathering a sample has undergone and resultant matrix mineral species in the sample.

The more general-purpose or robust partial extraction techniques, such as **Regoleach**, will always see or produce an anomaly detected by total analytical methods. (In some circumstances Au may provide an exception to this). The reverse however, is not true. There are many instances where total analytical methods report below limit of detection (BLD) values but partial leach analyses produce good coherent multi-element responses. This is generally because of the much lower levels of detection available through the use of ICP-MS and separation of anomalous signature from a variable background. Some leach methods are better than others for different elements and in different environments hence the detection limits for different leaches vary.

While partial leach analysis offers advantages over conventional total methods in weathered terrains there is a trade off. The greater analytical sensitivity means greater susceptibility to superficial factors, (or at least the effects of this are more obvious), and these need to be assessed by analysing for a number of elements that most strongly reflect surface geochemical processes to assist in data interpretation. The most

important in this regard are iron, calcium (calcretes), sodium, magnesium, potassium and sulphur (sulphate e.g. gypsum). The presence of iron oxides, calcretes or gypsum gives an indication of likely soil pH values or salinity for example, or sites with seepages etc. This in turn influences the extent of dispersion of "mobile" elements transported in ground water.

The source of any partial or selective leach anomaly may be from beneath or to one side of it. The way to discriminate the source direction is by eliminating one or the other by careful logging of sample sites and the local regolith and geomorphic terrain. In many deeply weathered or eroded terrains the re-distribution of products such as pisolites, lag or scree by sheet wash erosion into drainage systems creates a supply of potentially anomalous material that can release analytes of interest (Cu, Zn, Pb, As, Sb etc). Buried accumulations of these weathering products may break down under hydration, redox change or pH change to release ore elements into the ground water system and ultimately into the soil profile where they may report as anomalism. Such anomalism may be many kilometres removed from the original source of mineralisation. Sites of silcrete or calcrete deposition are also often places where other trace elements of interest also precipitate (largely due to evaporative concentration). These sites should be noted and treated separately in data analysis, as they are potentially likely to be more anomalous than sites in the surrounding landscape.

An elevated value of any single element might not necessarily reflect the presence of unexposed mineralisation. It is only likely to do so if the mineralisation outcrops. In most geochemical surveys it is assumed that anomalism and mineralisation go hand in hand and that mineralisation is shallow beneath an anomaly peak. This is a reflection of the simple methods by which data are processed without due regard to sample environment variation. Big numbers are not always the best numbers and the big numbers may only represent the transported part of an anomaly and be secondary in character for reasons outlined above. In weathered and covered terrains we need to adjust our approach in data assessment to use low analytical values and to accurately identify anomalism within them. By using partial leach methods and analysing for a wide range of analytes, it is possible to use co-anomalism and presence or absence of ore associated elements, often in a qualitative sense, rather than the absolute magnitude of single elements, to identify anomalism.

In the search for buried mineralisation we may need to look for some expression of an alteration halo geochemistry characterised by elements other than the ore elements sought in the ore body. These may define zones of depletion rather than enhancement. Remember that the geochemistry and alteration may be confined to narrow shears, fractures

or other pathways rather than being pervasive through the bulk of the rock, or be expressed in an erratic manner along a vein or fault system. We therefore need to analyse for a range of elements that will identify both the ore minerals and their associated trace ore or alteration halo associates. It generally requires low levels of detection to separate halo signatures from variably weathered, unmineralised and unaltered bedrock signatures. Elements analysed should include both anionic and cationic species.

ALS Chemex offers the widest variety of selective leaches in the industry. The company has long recognised that there is no such thing as a magic solution that is applicable in all geological environments. It co-designed **Regoleach** (ALS Chemex method **ME-MS08**) with Rutherford Mineral Resource Consultants as a general purpose and robust partial leach method suitable for reconnaissance geochemistry and able to be used in a wide range of terrains with variable geochemical environments. ALS Chemex staff geochemists and Rutherford Mineral Resource Consultants can discuss your needs for this or any other leach process. They will also help with any other analytical method selection or exploration project strategy, assist you with orientation surveys, sampling procedures and even get you started with data reduction.

**Neil Rutherford - Rutherford Mineral Resource Consultants**

Telephone / Facsimile: +61 2 9665 8263

Web: [www.geochem.zip.com.au](http://www.geochem.zip.com.au)

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