Probing the Subsurface with Selective Extractions of Soils: Models for the Great Basin

J. Robert Clark, Enzyme-ACTLABS, LLC and Gregory T. Hill, Consulting Geologist

Since the introduction of the Enzyme Leach^{SM} (EL) ten years ago, substantial refinements have been made in selective extraction technologies applied to surface soils. Numerous research studies and extensive experience with exploration projects have resulted in improved interpretive models. Initial USGS studies at Sleeper, Rabbit Creek, Mag, and Clay Pit led to the definition of the "oxidation suite" of elements and the "oxidation anomaly" model. More recent work at locations around the world have led to the recognition of spatial patterns related to the geometries of mineralized bodies and related subsurface structural features. In some cases, dip directions can be ascertained, and there are situations where multiple selective extractions can be used in tandem to aid in developing a 3-dimensional understanding of the subsurface. Data from numerous Great Basin soil surveys show that in most cases, Au in selective extraction data accompanies anomalies that are diagnostic of Carlin type and low sulfidation epithermal Au deposits.

Most EL anomalies associated with Au deposits in the Great Basin fit the oxidation anomaly model. Oxidation anomalies were first observed in northern Nevada at the Sleeper Mine and the Rabbit Creek Mine in a USGS study that was done in 1989 and 1990, using samples collected by Tom Nash and Maurice Chaffee and analyzed with the help of GSI and Lawrence Livermore Laboratory. Trace element patterns and associations observed at those locations and at other locations in the Great Basin were used to develop the model. A suite of elements that form gaseous halides (Cl, Br, I, V, As, Se, Mo, Sb, Te, W, Re, Au, Hg, Th, and U) was observed to form very low concentration, but high contrast anomalies. These associations and patterns did not fit any existing geochemical paradigms. Members of this suite commonly associate in zoned halo patterns at the surface, bounding reduced bodies in the subsurface. Even though these early studies were often limited to one or two lines each with small numbers of samples, the observations have been widely applied throughout much of the Great Basin as well as many other parts of the world. Hundreds of oxidation anomalies have been observed on six continents, in a variety of climates, and even in marine environments.

Over time, improvements in analytical technology have resulted in 10X to 100X reductions in detection limits and much improved analytical precision. As a result, concentrations of nearly 70 elements can be determined below their normal background values. This has made it possible to precisely define characteristics of low-level responses developed among much of the periodic table. These include spatial trace element differentiations, nested halos, pinwheel patterns, and abnormal element depletions. All of these features characterize robust oxidation anomalies and are produced by the flow of electrical currents within reduced chimneys. The observed patterns indicate that most oxidation anomalies are strongly structurally controlled. Therefore, a great deal of subsurface information can be ascertained, particularly when selective extraction data are coupled with geological and/or geophysical data.

The early Great Basin studies have been followed by many other proprietary and nonproprietary studies of selective extraction responses above Nevada Au deposits. Some highlights are summarized here. Gold responses clearly define a halo within an oxidation anomaly above the Marigold 8N Carlin type deposit as described in a 2000 Hill and Clark study. As predicted by the model, zoning, nested halos, and depletions characterize the oxidation anomaly above the 8N Au deposit.

Through the 2000 Nevada Selective Leach Orientation Study, coordinated by Todd Wakefield, EL, aqua regia (AR), and fire assay (FA) data were acquired in orientation surveys over a +4 M oz. Au resource at Mike (on the Carlin trend), and blind and/or buried ore zones at four Nevada Au mines: Ken Snyder, Archimedes, Rodeo, and SSX. Although the geochemical compositions associated with each of these deposits vary significantly, most have diagnostic surface responses that include zoned and nested halos, and depletions. Gold responses occur within the EL signatures at all of these deposits except Mike. Conventional FA also shows subtle Au responses that accompany the oxidation anomalies but these are of significantly lower contrast than the EL Au responses. Because of the extremely low contrast between anomalous and background FA Au responses and a lack of clear oxidation anomaly patterns among the FA data, most FA Au peaks associated with buried or blind mineralization would likely be dismissed as background values. At Mike, background soil Au values were determined by FA but these do not indicate the mineralized zone. At Mike and Rodeo, AR results provide good indications of mineralization as do the EL data. However, the EL results show halos with up to 3 times higher contrast than the AR results. Surface responses associated with the other three deposits are much more distinctive with EL and are extremely subtle or absent with AR.

Three-dimensional geological models can be developed or enhanced by the use of selective extractions. For example, indications of dip or plunge have been found in the geochemical distributions above several buried deposits. A 1998 study by Jim Yeager at King Tonopah, shows a strong halo feature around an epithermal system and dipping Ag vein. Linear highs in a number of elements occur over the vein; however these apical responses are not coincident. Instead they parallel each other. This is apparently due to various elements being liberated at different depths, and in turn, provides a technique for determining dips within the district.

In some situations, members of the oxidation suite can occur apically over deeply buried mineralization as a result of specific redox conditions within the electrochemical cell. For example, at the Antimonio Au deposit, a 750,000 oz. resource in northern Sonora, Au, As, and Sb highs occur over the top of the Au zone. These Au and pathfinder responses are haloed by Cl, Mo, and other oxidation suite elements which are offset from each other as a result of the plunge of the Au zone. Three overlying detachment fault slices appear not to have influenced the patterns originating from the mineralized zone beneath.

An ongoing study of the I-10 Cu skarn in southern Arizona demonstrates that pairing two selective extractions, EL and TerraSol (TS), with geology, yields a 3-dimensional view that conforms with geologic information but also suggests important (feeder?) fault zones not seen through drilling. At surface, a halo around a Mo-Cu porphyry stock at 1200 feet beneath the southern end of the skarn can be seen in the EL data but is less apparent in TS data. Niobium patterns in the two selective extractions show different sets of structural features. When compared to the geologic block model for the skarn, the TS Nb distribution appears to be showing shallow plumbing while EL Nb suggests a deep feeder structure. This possible feeder zone may have provided access for hydrothermal fluids that migrated from the porphyry system upward and laterally into the forming skarn. The deep feeder zone has never been drill tested.