

Soil Gas Carbon Dioxide and Oxygen for Mineral Exploration



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Introduction

Considering the body of work on soil gas applications, one reasonable interpretation is that direct measurement of carbon dioxide and oxygen in soil pore space gases is one of the most cost effective alternatives for detecting buried mineral deposits. These two gases occur at percentage levels, hence they are easily measured in the field with relatively inexpensive equipment. There are technical issues that must be carefully considered when implementing CO₂-O₂ surveys, but this review will show that these are manageable. This short discussion will focus on the carbon dioxide and oxygen technique, but it may be inferred that other gas species may hold similar potential by whole gas-based methods. Other contributions in this issue focus on various adsorption-based methods. The reader is referred to Klusman (1993) and other sources for thorough technical treatments of soil gas geochemistry concepts.

As practiced now, this CO₂ – O₂ soil gas method seeks to overcome problems with earlier trials through larger samples, field-based analysis, monitoring meteorological and background variation, and improved interpretive techniques. The field equipment is displayed in Figure 1. Careful

Instantaneous CO₂/O₂ Method Hardware and Sampling Protocol

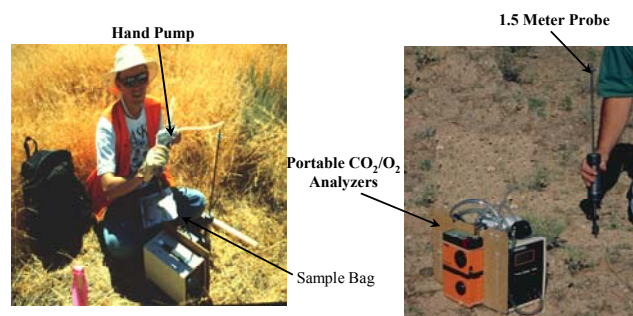


Figure 1 - Field Equipment for CO₂/O₂ Method

sampling and real-time analysis ensures that a stable sample is collected. These surveys always include base stations so that background conditions and meteorological variation can be accounted for. Very often, the interpretation of geochemical data is focused too much on numerical absolutes. This sort of real-time soil gas data is dynamic and complex, the patterns of peaks and valleys may be more significant than the magnitude of any of the spikes. In general, the data tend to map two types of features – large reducing bodies consuming oxygen over a large area and narrow, structurally or “plumbing” defined features that control gas movement.

As discussed in the overview, the fundamental premise behind much of soil gas geochemistry is the oxidation potential (Eh) of the mineral deposit and surrounding environment. In its simplest interpretation, this means that a reduced mineral deposit should consume oxygen as it oxidizes. The process of mineral deposit oxidation generates acidity, which may also attack any available carbonate and generate carbon dioxide. It is also true that microbial activity in the subsurface generates carbon dioxide. Therefore, elevated carbon dioxide and depleted oxygen in the soil atmosphere may be indicative of buried mineral deposits.

Case Studies

Two different types of soil gas responses can be seen in the following examples from copper skarn and intrusive-related gold prospects. Figure 2 is a profile across the Ruby

Ruby Star Cu Skarn, Arizona, USA Line 21700E - Looking West

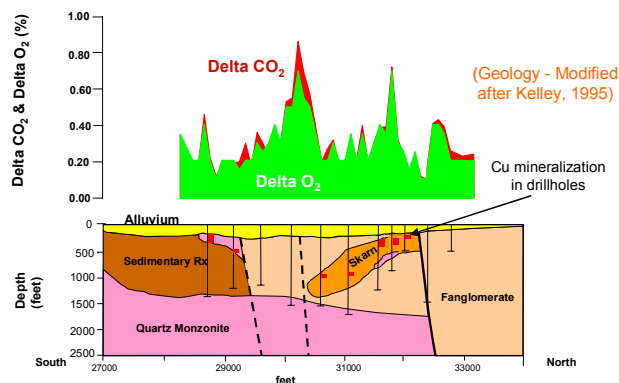


Figure 2 - Soil Gas Profile from Ruby Star Deposit, AZ

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Star deposit in the Mission-Pima district of southern Arizona, USA. The soil gas CO₂ and O₂ data are charted as the absolute values of the difference between down hole concentrations and atmospheric values, or Delta CO₂ and Delta O₂. Peaks in carbon dioxide represent increased CO₂ relative to atmospheric values, whereas peaks in oxygen are depletion relative to atmospheric content.

In this example, there is a strong structurally-controlled CO₂-O₂ response to mineralization. The biggest spike is a multi-point anomaly in elevated CO₂ and depleted O₂ over an interpreted fault near the middle of the line. This fault almost certainly cuts sulfide mineralization in the mega-breccia skarn body at depth. Another sharp spike occurs just south of a major fault that bounds the skarn block. There are copper sulfide drill intercepts directly beneath this area. A few more modest spikes occur over drill intercepts in the skarn block and in the sliver of quartz monzonite near the south end of the line. Note the strong correlation between the patterns in carbon dioxide and oxygen.

The next example is from the Kori Kollo district of Bolivia (Figure 3). The traverse is from an area of drill-intercepted base metal sulfides with anomalous gold to the

Soil Gas Orientation Survey at Kori Kollo, Bolivia

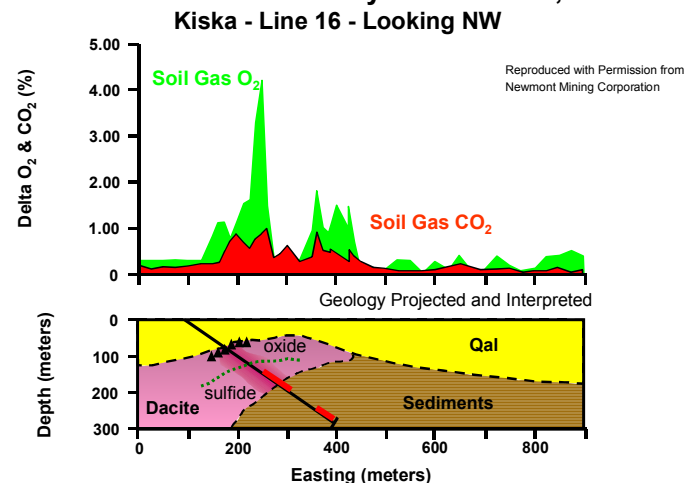


Figure 3 - Soil Gas Profile from Kiska Prospect, Bolivia

south and west of the Kori Kollo mine. The mineralization in this area occurs in sulfide veins associated with dacite porphyries. Here there are drill indicated base metal rich sulfides at two different intervals in the intrusive and sedimentary rocks. The overburden at Kiska is very fine grained, perhaps lacustrine sediments, and rain water pooled at the surface in many areas.

The data from Kiska seem to reflect the vertical projection of the sulfide intercepts with very significant oxygen depletion and moderate carbon dioxide enrichment. The anomalous patterns in both gases are relatively broad, apparently indicating significant widths of sulfide minerals. There is insufficient geological control to assess whether or not this response is due to faulting. There is also a striking difference between the carbon dioxide and oxygen signatures of this mineralization. Based on similar patterns observed

in data from other projects where major precipitation events interrupted sampling, it is likely that this strong disequilibrium phenomenon is related to recent precipitation in the survey area. It is possible that bicarbonate under-saturated rainwater infiltrating the soil profile dissolved carbon dioxide, thereby suppressing the CO₂ soil gas response.

Conclusions

These examples demonstrate the utility of soil gas carbon dioxide and oxygen for mineral exploration beneath overburden. The most common types of anomalies are reflected in these two data sets – structurally controlled spikes versus soil gas plumes over reduced (sulfide) bodies. There is also evidence in the Bolivian data of meteorological effects on soil gases and how the response to mineral deposits tends to overwhelm those effects. It is also important to note that this method requires extraction of soil pore space gases, so it cannot be applied in areas of saturated ground or extremely shallow water tables. The reader is further referred to **EXPLORE** no. 119, April 2003, for two more examples of CO₂/O₂ data. Properly managed with base stations, calibrations to atmospheric concentrations, and careful sampling protocols, this inexpensive method can be an effective part of an overburden exploration strategy.

Perhaps the spread of soil gas CO₂/O₂ geochemistry as a mainstream exploration tool is hampered by a lack of commercial providers of the service. Virtually all of the work done in this field has been conducted by company geochemists and geologists or a short list of consulting geochemists. There is a relatively steep learning curve when deploying any new technology, but few methods can go from testing to targeting as quickly as this simple soil gas method.

References

- Kelley, D.L., 1995, Geochemical orientation studies: Ruby Star project, Pima County, Arizona, USA: Unpublished report, BHP Minerals International Exploration, Inc, Denver, Colorado, 16 p.
- Klusman, R.W., 1993, Soil gas and related methods for natural resource exploration: John Wiley & Sons, Chichester, UK, 483 p.

