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BASE METALS PROSPECTING IN KAGERA REGION, TANZANIA USING REMOTE SENSING AND BIOGEOCHEMISTRY ANALYTICS

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ABSTRACT

This paper explores the use of biogeochemistry as a means for conducting geological prospecting in search of economic grade anomalies of precious metals, base metals and rare earth elements. The use of randomized soil sampling for geostatistical coefficient calculations and aeromagnetic remote sensing systems in conjunction with biogeochemical prospecting for ferromagnetic elements is examined. The paper concludes that the evidence presented indicates that bioprospecting can be an extremely powerful economic geology tool for conducting rapid and cost effective micro-targeting mineral discovery.

KEYWORDS: biogeochemistry, bio-prospecting, nickel, platinum, cerium, yttrium, lanthanum, manganese, rare earth elements, geostatistics, mathematical geology, economic geology, aeromagnetic, ferromagnetic, paramagnetic, bastnasite

INTRODUCTION

This paper details a mineral bio-prospecting expedition to the Buhamila area of Kagera, Tanzania conducted during the period from March 2013 to June 2013. This expedition occurred during the just prior to and during the “long rains” or the main rainy season, and consisted primarily of biogeochemistry (BGC) bio-sampling techniques with limited random soil sampling intended to augment potentially weak Ni-in-plant tissue signal data. The primary objective of this prospecting was economic Ni, Co and PGMs (Platinum Group Metals) anomaly concentrations however the author was interested in any potentially economic mineral anomaly including REEs (Rare Earth Elements). Accordingly, assay analysis of the biogeochemistry plant tissues made use of Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to detect a 53-element suite within the collected tissue samples after proper laboratory preparation by controlled ashing and then placing the sample material on an aqua regia digestion. Baseline sensitivity of the analysis technology ranged from 0.2 ppb for Au up to 0.01 ppm for Cd.

SITE DESCRIPTION

The area is located within the Mesoproterozoic Karagwe-Ankolean sequence within the Kibaran Fold Belt structure of northwestern Tanzania (fig. 1). The sedimentary features of the Karagwe-Ankolean rocks are massive, current bedded, ripple-marked sandstones and interbedded rhythmically laminated shales and siltstones. The sediments reflect shallow-water deposition, with argillites, phyllites, low-grade sericite schists and quartzites. During orogenisis the sediments were metamorphosed and are now quartzites, argillites, phyllites, slates and schists (Barth, 1990), although the level of metamorphism was relatively low in the observed surface metasedimentary outcropping samples.

The Karagwe-Ankolean sequence covers the northwestern part of Tanzania on the border zone between the Western Internal Domain and the Eastern External Domain of this orogen. The rock outcroppings are predominantly metasediments characterized by the intrusion of mafic intrusive bodies at approximately 1.275 Ga (mainly basic sheets), A-type granitoids at 1.250 Ga and post-orogenic tin granites with an age of approximately 1.0 Ga.

Figure 1. Buhamila area, Kagera region, United Republic of Tanzania, June 2013.

The Buhamila area was initially targeted because of both its relative proximity to the corporate mining camp of the author's client in the Geita Province of Tanzania, making it an ideal test case for long range intermediate duration prospecting surveys. Furthermore, the author's mineral exploration client conducted an aeromagnetic survey of the entire Kabanga corridor in northwestern Tanzania in the 1990s, and such data would act as a validation check on some of our large-scale findings due to the ferromagnetic characteristics of Ni and Co. Lastly, because of the nearly complete lack of other (non-Ni) geochemical exploration data for the region, our rapid mineral exploration capabilities inherent in BGC surveys (Woolman and Yi, 2013) would provide excellent exploratory value on a cost-per-observation metric relative to other large-scale prospecting methods. As efficiency metric, our combined team of eight botanists and geologists and laborer support personnel was able to conduct the bio-prospecting survey for this 92 km^2 mineral license in approximately three months' time, obtaining almost three thousand discrete sets of plant tissue observations during that period.

FIELD SAMPLING METHODOLOGY

Station spacing (area between plant tissue samplings on the same bearing line) was defined at 50m intervals, with line spacing (the distance between bearing vectors) was set at 200m. During precious metals bio-prospecting surveys in the past, station spacing was typically conducted at 200m intervals. The determination was made to increase the granularity in the exploratory dataset by going down to 50m intervals because of the known propensity for weak signals in both Ni and PGM signatures in plant species which do not hyperaccumulate Ni (the majority of species). While it is known that 256 species hyperaccumulate Ni (with at least 48 species being native to Cuba) (Robinson, *et al*., 1997), most of these plants are curiosities and not sufficiently abundant to conduct an exploration biogeochemistry survey (Dunn, 2007). A potential solution to the above-mentioned weak-Ni absorbing plant species commonality is presented in the below section on Analytical Methodologies. This increase in granularity due to reduced station space sampling did not significantly delay the data gathering process and greatly increased the scope of our analytical capabilities, and may have demonstrably aided in the detection of the cerium-based REE mineralization anomalies due to their relatively discrete area coverage.

ANALYTICAL METHODOLOGY

Known potential indicator elements for Ni include Cr, Cu, Zn, particularly in sulphide-rich mineralizations (Cu-rich), and the author's correlation matrix made use of these indicator elements to validate anomaly detection plots. This multidimensional correlation matrix with dimensionality factors based on plant species, seasonality, soil and indicator elements was used to optimize the response ratio metrics upon analysis of lab sample results before splining the calculated BGC response ratio data to the geophysical map. Calculation results were defined by the above cross-dimensional differentiators and tailored to each intersecting combination for each coordinate set. Uniquely in the case of Ni observation data, it was determined by the author that in order to determine the influence of Ni levels in plants with uptake by non-hyperaccumulating species, a statistical tool known as the biological absorption coefficient (BAC) was required to be calculated and plotted and serve as a bootstrapping methodology (signal enhancement). The BAC is the ratio of the element concentration in the soil to that in plant species (Kabata-Pendias, 1984), which would act as a statistical weighting factor to augment a valid signal where amplitude might otherwise go unnoticed in a normal response ratio analysis. The BAC was calculated after determining a suitable number of random soil samples to be made to create a statistically valid confidence level (.95) with a suitable margin of error. This would provide sufficient coverage for the survey area with randomness to not favor any particular plant species or soil type, and due to the low number of soil samples required from the use of a statistical sampling methodology, not incur any significant budgetary costs or slow the work being done to any significant factor.

In fact at BK 199 our BGC Ni signal is indeed weak due to plant metabolic processes, but remains statistically valid. The BAC weighting appears to solve the analysis problem in this case and has the future potential to make similar improvements in weak signal conditions with bio-prospecting and provide a reasonable facsimile to traditional soil sampling data, allowing for direct comparison of BGC data to soil data where a proper BAC weighting methodology has been applied.

After the application of BAC coefficient weightings to the BK 199 Ni data (BACs were calculated for each plant species with sufficient Ni observations), my standard set of response ratio calculations were applied which was first determining the background (median) level of Ni for each plant species by soil and seasonality, and then classifying observations as "yellow" (mild Ni values of interest) as being 20 times the 25th percentile with the BAC weighting, and then classifying observations as "red" (strong Ni values of interest) as being 50 times or greater than the 25th percentile with the BAC weighting. Figure 2 shows the resulting BAC values for each plant species.

The results, in the author's opinion, were excellent when overlaid to the 1990s-era aeromagnetic map (fig. 3). Of possible interest is to note that the aeromag map predates commonly available commercial GPS units and as such there appears to be some minor deviation in anomaly locations relative to some of the anomalies indicated by the BGC results (yellow and red pixels). Figure 3 shows an "annotated" map circling in purple the BGC / aeromag anomalies to the east, as well as a purple vector outline showing the central Ni BGC anomaly trend. Note that 8 of the 12 "red" pixels appear in the central "hot zone" for the existing Ni aeromag anomaly, and 3 of the remaining exist within or on the edge of the main Ni anomaly. One single red pixel appears to the west in a blue region of the Ni aeromag anomaly. It is possible that this aeromag data is inaccurate to the west due to

MGU species, Ni Max: 3.3 ppm	***MKY species, Ni Max: 39.6 ppm***
MGU species, Ni Min: 0.05 ppm	***MKY species, Ni Min: 0.6 ppm***
MGU species, Ni Mean: 0.894 ppm	***MKY species, Ni Mean: 9.05 ppm***
MGU BAC Coefficient: 14.715	***MKY BAC Coefficient: 6.3027***
MLM species, Ni Max: 27.2 ppm	***TBT species, Ni Max: 27.5 ppm***
MLM species, Ni Min: 0.4 ppm	***TBT species, Ni Min: 0.2 ppm***
MLM species, Ni Mean: 5.50 ppm	***TBT species, Ni Mean: 3.384 ppm***
MLM BAC Coefficient: 4.562	***TBT BAC Coefficient 15.23***

Figure 2. Ni observation statistics by plant species, with calculated BAC coefficient metrics.

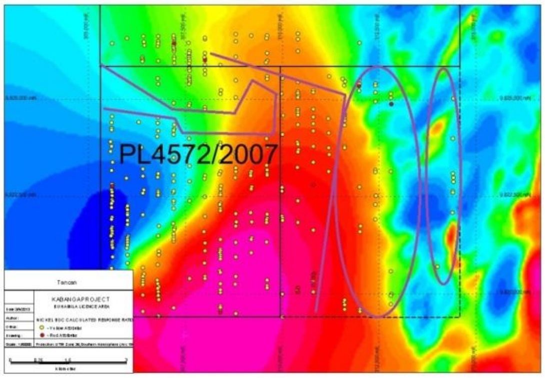

Figure 3. Ni response ratio plot overlain with aeromagnetic anomaly plot. Data

compliments of Tanzanian Royalty Exploration Corporation (NYSE:TRX).

navigation discrepancy or the BGC trend may be uncovering an Ni signal that is deeper than the aeromagnetic equipment was able to detect (taproots in some cases can extend to 40m depth and biological capillary action would allow such deep taproots to uptake mobile metal ions from a depth even greater).

Likewise, a cerium/lanthanum/ yttrium set of anomalies has also been detected in a consistently precise ratio at the same coordinates, with an R2 statistical correlation relationship of an astonishing .96 and .98 respectively, a value that is so high that to me this indicates a mineralogical relationship between the three elements in this area, which would have to be bastnasite as no thorium or neodymium was detected (ruling our monazite). Cerium is by far the dominant of the three elements so in the interest of efficiency I analyzed the cerium signal primarily for purposes of anomaly plot generation. The cerium plot for this mineral prospecting license is also attached however it is also overlaid with the original aeromag map.

Finally, a significant manganese anomaly was also detected within the prospecting license book boundaries using the same methodologies, with multiple high-grade Mn and intermediate-grade Mn anomalies clustered in two primary sections approximately 2 kilometers apart along two trend lines. As Mn is a paramagnetic element, its relationship to aeromagnetic remote sensing techniques would expected to be minimal, so BGC analytics will be key to determining anomaly concentrations prior to drilling confirmations.

Additional follow up BGC exploration work continues in 2013 and 2014, including completion of a similar survey at Buhamila BK-198 and then moving northward into additional prospecting license areas of the Kabanga “corridor” in northwestern Tanzania bordering Rwanda to the west and Uganda to the north.

CONCLUSION

The data provided by the BGC surveys conclusively demonstrates that bio-prospecting when augmented by geostatical analysis techniques is an effective geological exploration process. Ferromagnetic anomalies detected by aeromagnetic remote sensing flight surveys convincingly confirmed the findings of Ni anomalies that were detected by the combined BGC surveys and geostatistical analytical procedures. This validation thus provides a high degree of confidence that the BGC exploration process is statistically valid for exploration of other types of base metal and precious metal elements at potentially economic-grade anomaly concentrations. Furthermore, the ability of biogeochemistry prospecting techniques to gather data from biological metabolic processes that uptake chemical elements from deep root systems, often deeper than 20m, provides a very powerful exploration tool for penetrating overburden that would otherwise hinder traditional discovery processes. While BGC does not replace traditional drill bit exploration, it can serve as an invaluable scouting system which will inexpensively and rapidly provide anomaly coordinates to speed up that process.

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