10IKC-223

EXPLORATION FOR CONCEALED KIMBERLITES IN BOTSWANA WITH TRACE ELEMENT SOIL GEOCHEMISTRY

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Soil geochemical surveys were conducted during kimberlite exploration programmes in various parts of Botswana. The samples were collected from the top 2.5cm of the Kalahari Formation sand surface horizon and were standardized to 40 litres. Orientation sampling was initially conducted over known kimberlites in the Jwaneng kimberlite field. The kimberlites are approximately 20m below surface. In addition, a single spot orientation sample was taken over a known kimberlite with high concentrations of kimberlite indicator minerals, but under 40m cover of Kalahari Formation sediments.

Sample Processing

All orientation samples were screened into three a +0.425 – 2.0mm fraction which was processed through a 1.0 tph mini-DMS. The concentrates from the DMS were optically examined for kimberlite indicator minerals. A 50g sample from the -180 micron fraction was submitted for Enhanced Enzyme Leach (EEL) partial extraction analyses at Activation Laboratories Ltd., Ancaster, Canada.

A 0.75 g sample of the -180 micron soil was leached in an enzyme matrix containing a glucose oxidaze solution at 30 ^{o}C for 1 hour. The enzyme in combination with the gluconic acid generated a very low level of hydrogen peroxide which dissolved the amorphous manganese oxide present. The released metals from the manganese oxides were complexed by the gluconic acid in the Enzyme Leach solution. This solution was analyzed by a Perkin Elmer ELAN 9000 ICP/MS. One matrix blank was analyzed per 49 samples. Two controls were run at the beginning and end of the group of 49 samples. Duplicate samples were leached and run every 10 samples. All concentrations are in parts per billion.

Results and Discussion

The Jwaneng kimberlites were characterised by surface concentrations of Th+U, V, Y, La, Nd and Eu. Ti, Ni and Cs were found to concentrate on the contact areas between kimberlite and wall rock. Li was depleted over the kimberlites, but relatively high in the soil off the kimberlites.

The single spot sample taken over a known kimberlite at 40m depth was only consistent with the shallower Jwaneng kimberlites in anomalous concentrations of V and Y+La+Nd. Only one ilmenite was recovered from the 40 l sample collected directly over the kimberlite.

Previous kimberlite exploration programmes over an area to the south of Jwaneng failed to produce indicators like ilmenite and garnet in anomalous concentrations and no kimberlites were discovered in the area investigated. Exploration samples collected over two outcropping features and two non-outcropping features observed through remote sensing techniques approximately 65 km south of the Jwaneng kimberlites produced trace element profiles similar to those observed over the known Jwaneng kimberlites.

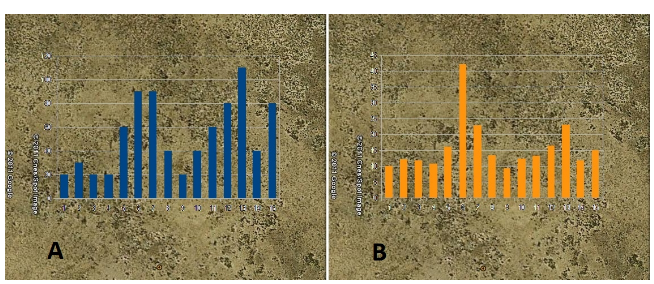

Figure 1: Trace elements concentrations of Ti (A) and Y+La+Nd (B) over geobotanical feature GK3 with "bunny ear" distribution pattern.

The "bunny ear" distribution of trace elements towards the outer limit of the GK3 feature (Figure 1) is consistent with distribution patterns of trace elements observed by Eccles (1998) over the Mountain Lake kimberlite, Alberta. These concentrations of trace elements may be related to strong oxidation cells associated with the movement of groundwater at the contact interface between the causative body and wallrock.

In contrast, the anomalous concentration of trace elements over the GK6 feature do not show a rabbit ear formation, but is focused over the central part of the feature (Figure 2).

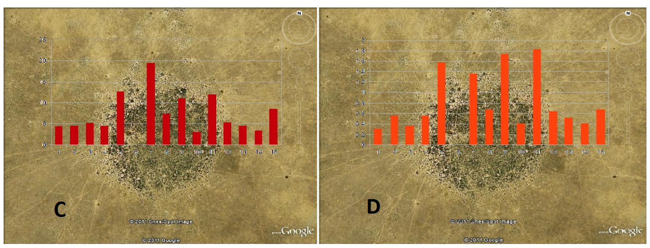

Figure 2: Trace element concentrations of Th+U (C) and V (D) over geobotanical feature GK6.

A characteristic and perhaps significant feature of the EEL results from the surface soils in this study is that several elements are not concentrated over the kimberlite, but on the contact zones between the kimberlite and the host rock.

Both Ni and Ti tend to be concentrated along the contact zones. This phenomenon suggests that the movement of these elements in a secondary environment may be controlled by factors associated with greater flow of groundwater along the contact zone and possibly higher oxidation levels.

Chondritic normalized values of Y+La+Nd (Anders and Grevesse, 1989 x 1.3596 after Korotev, 1996) for profiles over features GK3, GK4, GK5 and GK6 suggest varied conditions may give rise to the anomalous concentrations of these REE elements (Figure 3). The rabbit ear formation and very high values observed at GK4 are indicative of the shallow source body as the source of the REE's. The country rock in this area is banded ironstone and unlikely to be the source of the Y+La+Nd values as observed. The apical signatures generated by the results from GK3, GK5 and GK6 are typical of an anomalous source of these REE elements close to surface. Groundwater sources from boreholes belonging to livestock farmers at GK6 indicate the presence of strong groundwater flows. No water analysis has been undertaken to date. No groundwater boreholes have been observed at the other locations.

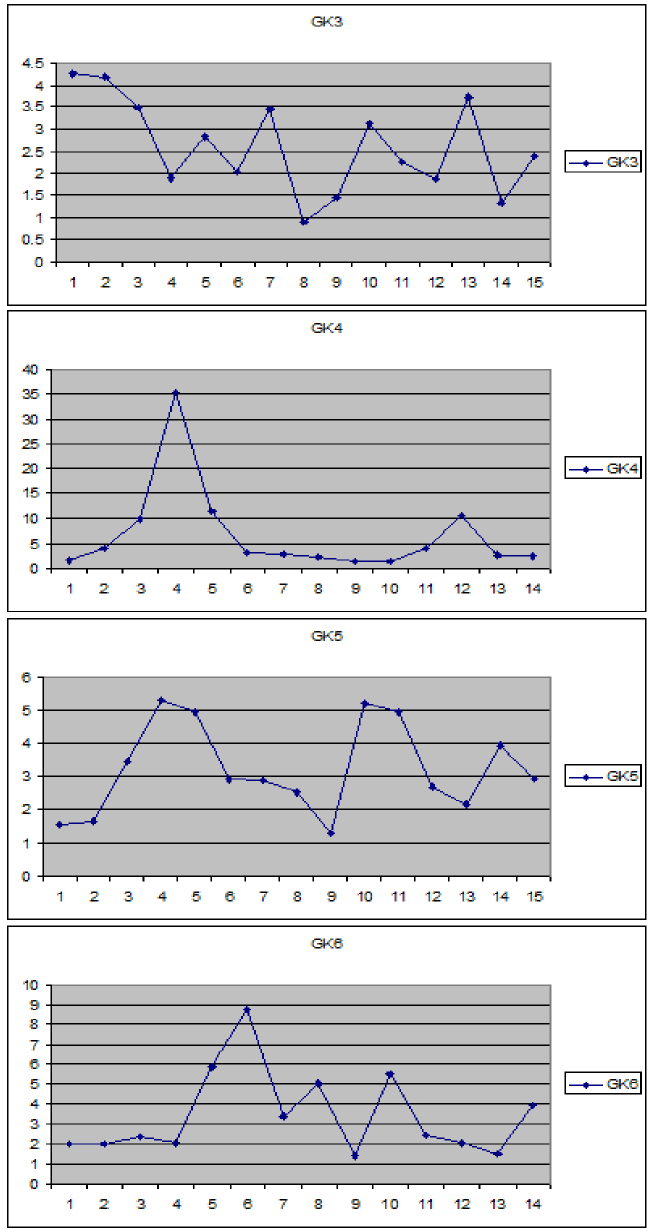

Figure 3: Chondritic normalized Y+La+Nd profiles over GK3, GK4, GK5 and GK6. GK4 and GK5 are features not overlain by Kalahari Formation sediments.

No Cr was detected in any of the samples, be that orientation or exploration. The absence of Cr in all the EEL analyses in this study is most likely due to the immobility of trivalent Cr in groundwater.

Anomalies in trace elements are not always due to the presence of certain elements in the target source, e.g. REE's and Ti relative to country rock, but sometimes due to a paucity of particular elements relative to the country rock.

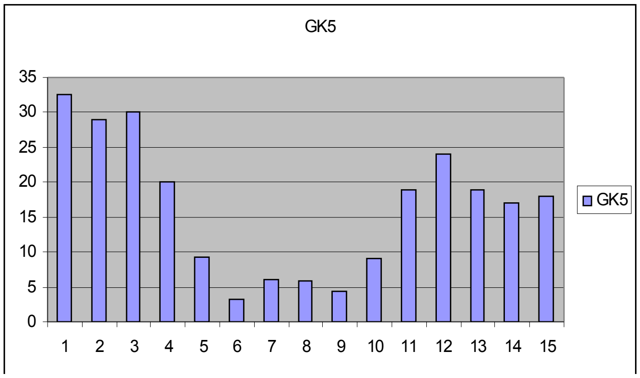

Figure 4: Co sampled in a traverse across GK5 with host rock of brecciated Banded Ironstone Formation.

Co was found to be depleted over the GK4 and GK5 features relative to the country rock. The Kalahari Formation in the area is very shallow and the country rock consists of brecciated Banded ironstone Formation. The Co over GK5 is significantly depleted relative to the Co over the country rock.

There appears to be no anomalous concentrations of Nb above background level in the general Kalahari Formation. The results to date do not show a clear relationship between Mn and the trace elements associated with kimberlites. It is possible that other factors such as microbes and calcium concentrations in the groundwater may have additional influences on the transportation of elements to surface through the Kalahari formation soils.

Orientation sampling in western Botswana, in close proximity to a geobotanical feature, has produced zones anomalous in Th+U, V, Cs and Ti. An aeromagnetic survey was conducted over the area after the results of the soil geochemistry became available. A review of the aeromagnetic data located a magnetic positive anomaly co-incident with concentrations of trace elements suggestive of the presence of sub- Kalahari formation kimberlite. The correlation between the results from the orientation trace element survey and the results from the aeromagnetic survey has been found to be very positive (Figure 5).

The repeatability of traditional soil sampling for kimberlite indicators in the Kalahari environment of Botswana has been found to be erratic over several areas during a number

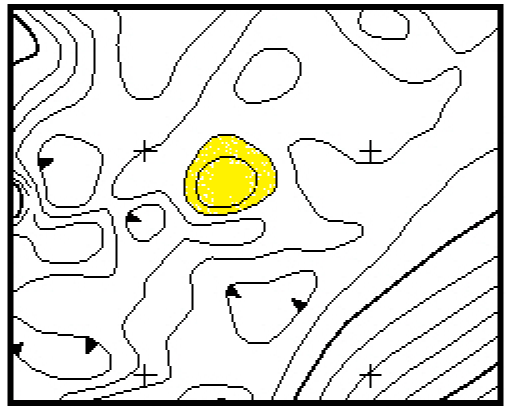

Figure 5: Aeromagnetic anomaly selection based on positive correlation with soil Ti and REE trace element concentrations in the soil.

of exploration campaigns spanning more than two decades of prospecting for diamonds. A concern has always been that a singleton kimberlite indicator in a soil sample may be considered to be background. Sampling over a known kimberlite which is known to have high concentrations of indicators in the kimberlite and buried 40m under Kalahari Formation cover produced a single ilmenite from a 40 l soil sample. This singleton may have been interpreted as background in the Kalahari environment where many singleton indicators have been reported from in the past. However, an analysis for trace elements of the same sample highlighted an anomalous concentration of V, Y+La+Nd and Sr relative to a control sample taken well off the pipe. The relative anomalous concentration of these trace elements from the sample over the kimberlite would have drawn attention to the sample location while the traditional kimberlite indicator sample results may have relegated the sample to background.

It is suggested that the use of EEL analysis to locate kimberlites buried under the Kalahari Formation in Botswana is more effective and accurate than the traditional use of indicator minerals.

References:

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