Experiment Report:
Spectroscopic properties of Lamproites and limestone rocks.

Project funded by Adrok Ltd. and conducted for

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Contents

ABBREVIATIONS

Adrok = Adrok Ltd
Tx = Transmitter
Rx = Receiver
TCC01 = Adrok typecasting chamber 01.

1.0 ABSTRACT SUMMARY

Lamproite and limestone rocks are analysed using Adroks technology. Observations of the differences between these two types of rock are of vital importance to Diamond exploration Consultancy Pty Ltd. This is because the ability to identify and distinguish Lamproites from Limestones is fundamental in diamond exploration.

2.0 INTRODUCTION

Worldwide Diamond exploration Consultancy Pty Ltd. provided Adrok with the following samples and information:

1. Three samples of limestone. These are typical examples from the area of interest, although in some beds, there could be a higher fossil content present. Samples: LS1, LS2 and LS3.

2. Three samples of Lamproite. These samples are from the outcropping of Big Spring 1 and are examples of the type of rock that Worldwide Diamond exploration Consultancy Pty Ltd. is looking for. However, these samples do not contain any intrusive limestone which is a typical occurrence in Lamproites elsewhere. Samples: BS1, BS2 and BS3.

3. One sample of calcreted cap rock. This sample comes from above a concealed Lamproite that has intruded a limestone area. Diamond exploration Consultancy Pty Ltd. suggests that this sample has most likely been altered by calcium, forming the cap rock. *In situ*, this sample would be covered by black soil, making it invisible. Sample: LEO.

Using the information provided by Diamond exploration Consultancy Pty, a simplified image of the typical geological subsurface that can be expected has been presented in figure 1.

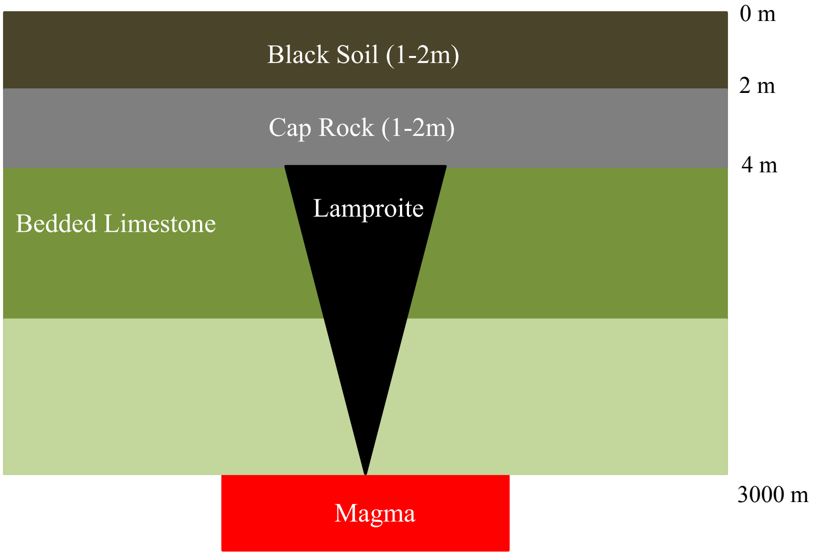


Figure 1: Simplified interpretation of subsurface Lamproite.

The differences between Lamproite and Limestone rocks are observed using Adroks *ADR* spectrometer. The variations that occur in the energy signals (primarily E-*ADR*, E-Gamma, E-Mean) are related to the physical and chemical properties of each sample. These parameters are used in order to characterise Lamproite and Limestone and distinguish the rock types from each other.

2.1 OBJECTIVES

1. *ADR* analysis of Lamproite and Limestone rock samples in order to calculate:

    a. *ADR* ratio (E-*ADR*)
    b. Energy mean (E-mean)
    c. Energy gamma (E-gamma)

2. Analyse dataset in order to characterise Lamproite and Limestone samples.

3.0 HYPOTHESES

Using *ADR* technology, it is possible to highlight the different spectroscopic features between a set of Lamproite and Limestone rock samples.

4.0 METHODOLOGY

The *ADR* analysis of the Lamproite and Limestone rock samples is performed by acquiring a set of 3 *ADR* scans for each rock sample. In addition to these scans, an empty chamber is acquired in order to subtract the empty chamber spectra from the rock spectra (i.e. to remove the background). In particular, the processes that are used in order to create these file can be summarised as follows:

1. The 'compare sample function' in Radamatic is used to select the best 2 (out of 3) scans for each sample.
2. These two scans are added using Principal Component Addition (*PCA*).
3. An X3Y3 smoothing filter is applied to the *PCA* (and empty chamber) image.
4. The image of the empty chamber is then subtracted from the *PCA* image.

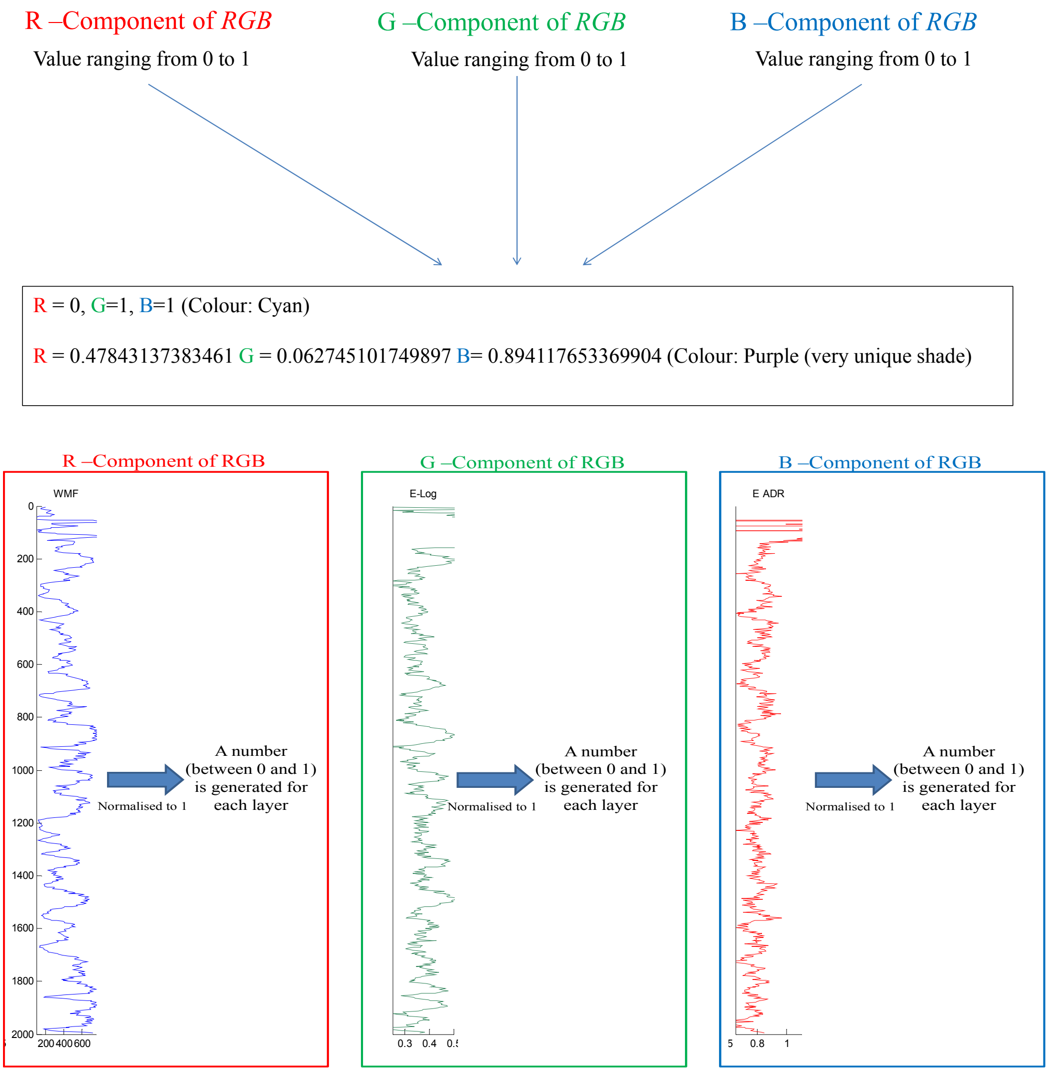
Before the measurements were taken, it was necessary to check the stabilisation of the A01-TCU01 unit. In order to do this, the source of the trace was referenced in the scope screen, by putting the 7th wave in the centre of the scope screen. After referenced, one scan every 20 minutes was acquired. Two parameters were checked, the central position of the 7th wave in the scope and the vertical "jitter" of the source trace.

An alternative way to verify the unit consistency is to record the reference wave in the scope, show the reference wave in the scope and check how the source wave moves, respect to the reference wave. Following stabilisation of the radio frequency source, a set of 3 spectra of the empty chamber were recorded. After these scans, the data for the 7 rock samples was acquired. The folder '*W:\x31102012-Project00137-DIAMOND'* contains all the scanned files and the subtraction sub-folder contains the files subtracted, where E-*ADR*, E-Mean and E-gamma are calculated.

Data Analysis

Among the numerous data analysis options that Adrok can employ, one such option is the creation of a false colour image from three separate analytical results. Details on how this is achieved are given in figure 2. The normalisation of analytical data to range from 0 to 1 provides a value that can be used as one of the components of an *RGB* image (in Matlab). Figure 3 demonstrates the type of image that can be expected. This example looks at sub-surface areas, creating unique colours for layers of fixed thickness, however, the same principles apply when comparing samples within the lab.

To Create an Red Green Blue (*RGB*) colour in Matlab, you need a value for each of the *RGB* components, ranging from 0 to 1:



R –Component of *RGB*

Value ranging from 0 to 1

G –Component of *RGB*

Value ranging from 0 to 1

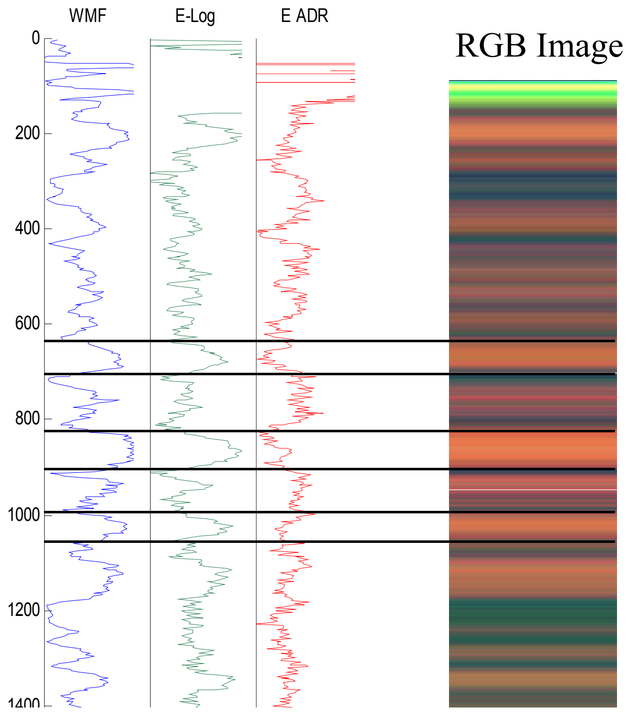
B –Component of *RGB*

Value ranging from 0 to 1

R = 0, G=1, B=1 (Colour: Cyan)

R = 0.47843137383461 G = 0.062745101749897 B= 0.894117653369904 (Colour: Purple (very unique shade)

Figure 2: Description of how Matlab creates a unique colour and how Adroks analytical components can be normalised to create one of the 3 *RGB* components that can create such a unique colour.



In this example, the peach areas enclosed within the solid lines correspond with high responses of the *WMF* and the *E-log*. It can be seen that the slight changes in the shade of peach appears to be determined by the small changes in the *E-ADR*.

Figure 3: Demonstration of the type of image that can be created using Adroks analytical parameters and how this presentation can aid the identification of similarities and differences between separately analysed samples.

5.0 APPARATUS

The chamber setup configuration is presented in figure 4.

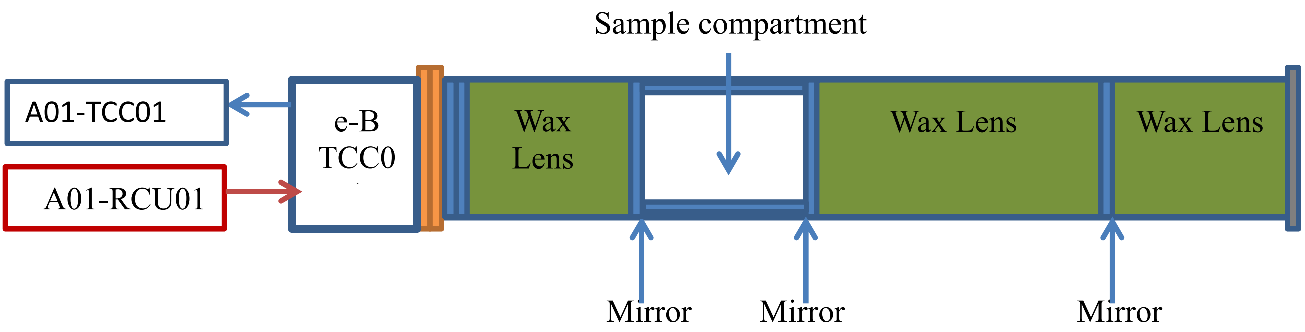


Figure 4: ***ADR*** chamber. The source A01-TCC01 is connected in the e-B TCC01 unit in the transmitter plug and the signal coming out from the e-B TCC01 unit is connected to the second channel of the A01-RCU01.

Figure 5 shows a rock sample in the chamber and figure 6 presents the source trace and the parameters at the moment of acquisition.

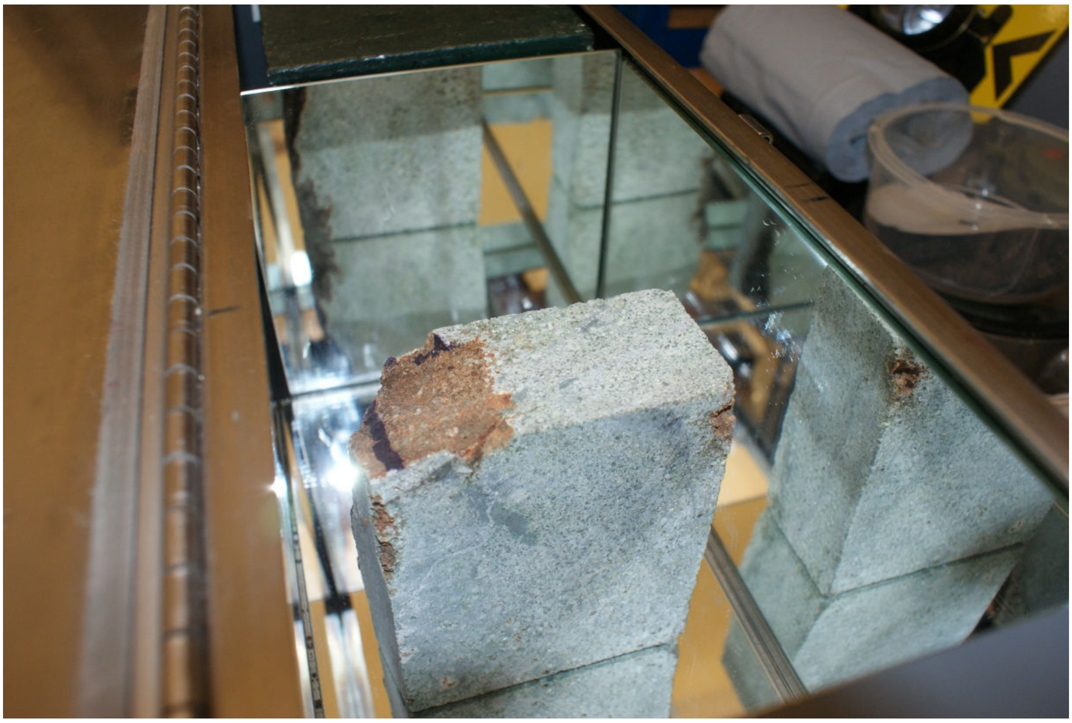
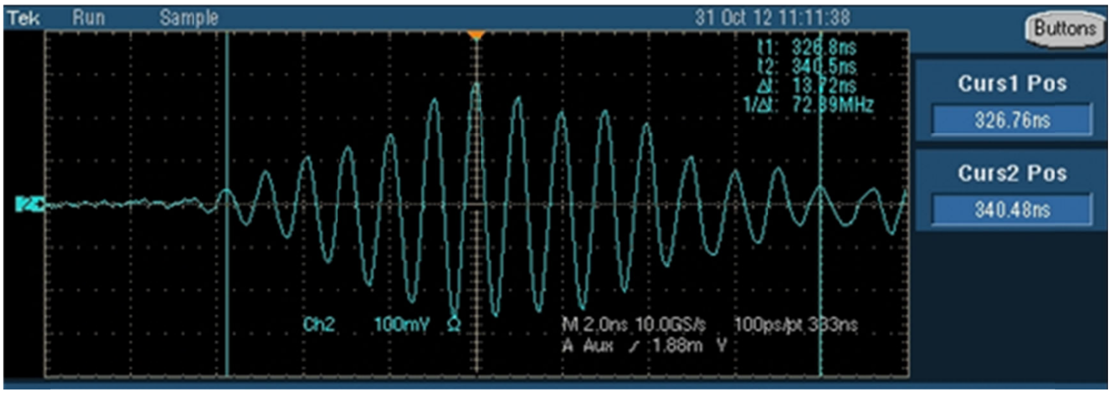


Figure 5. Example of sample position measurement



```
31 Oct 12 11:11:38
t1: 326.8ns
t2: 340.5ns
Δt: 13.72ns
1/Δt: 72.89MHz
Curs1 Pos 326.76ns
Curs2 Pos 340.48ns
Ch2 100mV Ω
M 2.0ns 10.0GS/s 100ps/pt 333ns
A Aux ⁄ 1.88m V
```

Figure 6. Stabilised receiver trace

6.0 TRANSMITTER (TCU) AND RECEIVER (RCU) SETTINGS

Repetition rate 10 KHz, fine PRF position 12 o'clock, delay coarse 12 o'clock, frequency setting 3, amplitude setting 6.

Chamber signal in CH2 triggered in external, Horizontal axis set to 2ns/div, Vertical axis set to 100 mv/div. The sampling was set to 10Gsample/second.

7.0 RESULTS

Table1 contains a summary of each samples; name, weight, volume and density.

SAMPLE	WEIGHT (g)	DIMENSION (cm)	VOLUME (cm3)	DENSITY (g/cm3)
BS1	1234	12 x 10 x 4.6	552	2.235507246
BS2	867	10 x8 x 5.5	440	1.970454545
BS3	946	9.2 x 10.5 X 4.5	434.7	2.176213481
LEO	933	11 x 10 x 4	440	2.120454545
LS1	1383	12.4 x 11.1 x 5.2	715.7	1.9323739
LS2	1183	13.5 x 8.5 X 4	459	2.577342048
LS3	1303	11.5 x 9 X 5.0	517.5	2.517874396

Table 1. Summary statistics for each analysed sample.

The *ADR* scans enable the Energy Gamma (E-Gamma), Energy Mean (E-Mean) and Energy *ADR* (E-*ADR*) to be calculated. These parameters have been combined to create a false image, as described above and which can be observed in figure 7. Values for *EGamma*, *EMean* and *EADR* were normalised (0 to 1) across all samples. These values were then used to create a Red (*EGamma*) / Green (*EMean*) / Blue (*EADR*), *RGB* stripe. This *RGB* image displays the way in which the three parameters vary relative to one and other (i.e. sample to sample).

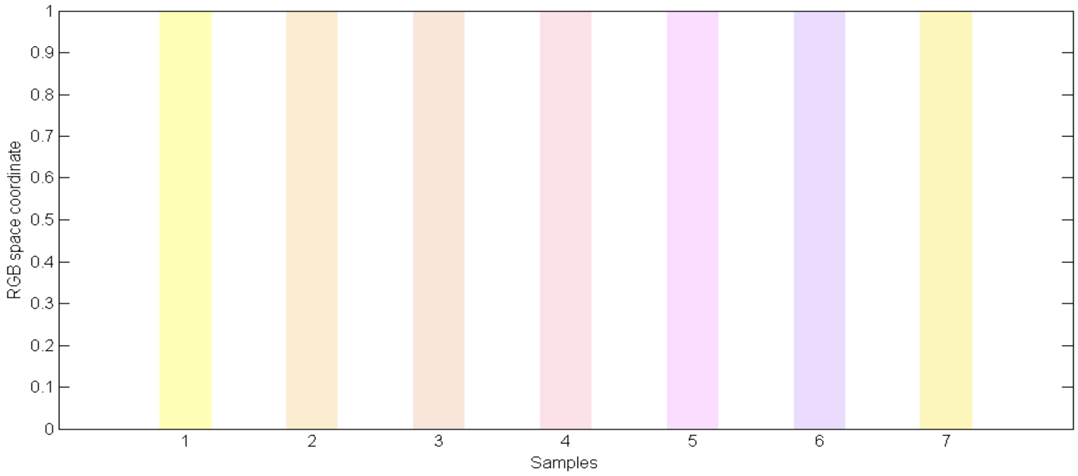


Figure 7. Lamproites and Limestone's *RGB* false image. The sample 1,2 and 3 are BS1, BS2, BS3, respectively, 4 is the LEO sample and 5,6 and 7 are the limestone samples, LS1, LS2 and LS3, respectively.

The *ADR* harmonic energy variation represents an additional feature related to the physical and chemical composition of the rocks. Figures 8 shows the *ADR* harmonic energy variation for the Lamproites samples, BS-1, BS-2 and BS-3.

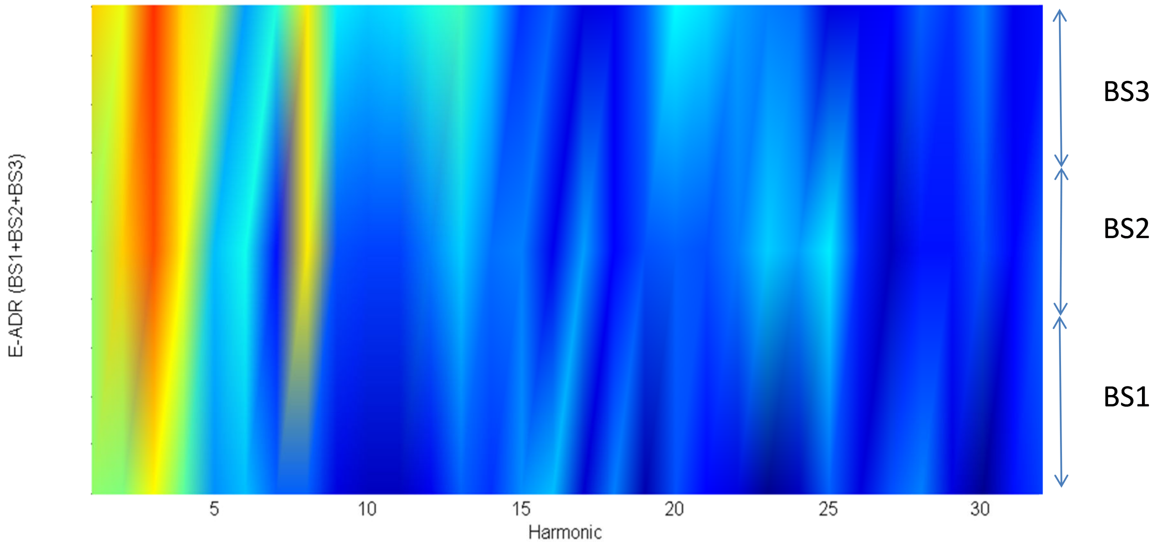


Figure 8. E-*ADR* harmonic energy variation for Lamproite samples BS-1, BS-2 and BS-3.

Figure 9 shows the E-*ADR* harmonic variation energy for the Lamproites (BS-1 to BS-3) including the LEO lamproite sample.

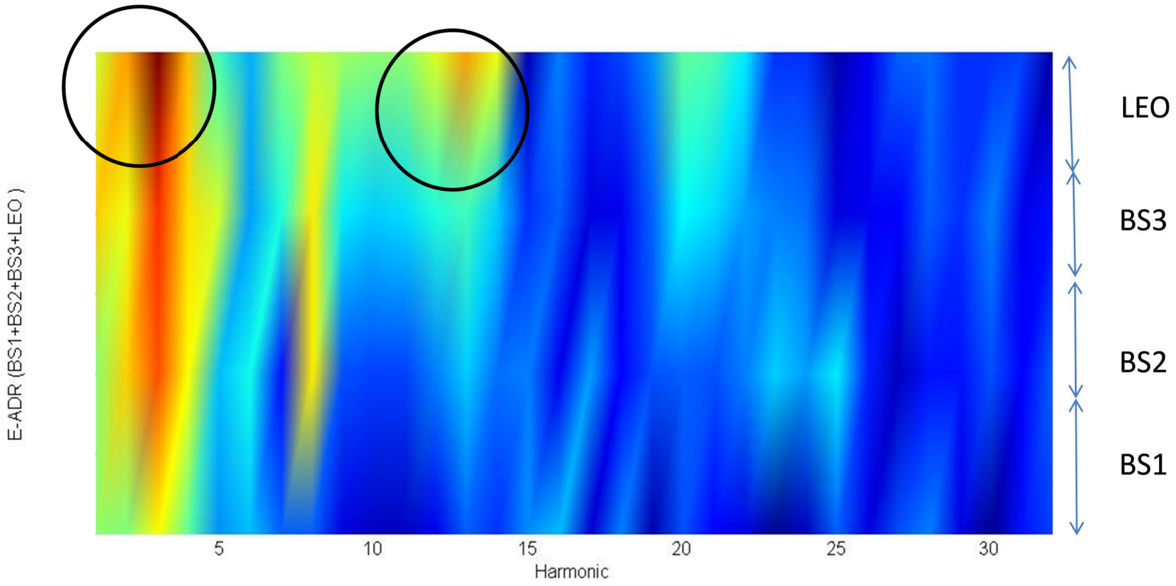


Figure 9. E-*ADR* harmonic energy variation for Lamproites samples (BS1+BS2+BS3+LEO).

Figure 10 shows the E-*ADR* Harmonic variation energy for the Limestone samples where they show a cleary different E-*ADR* harmonic energy pattern, compared to the Lamproite samples displayed in figure 8 and 9.

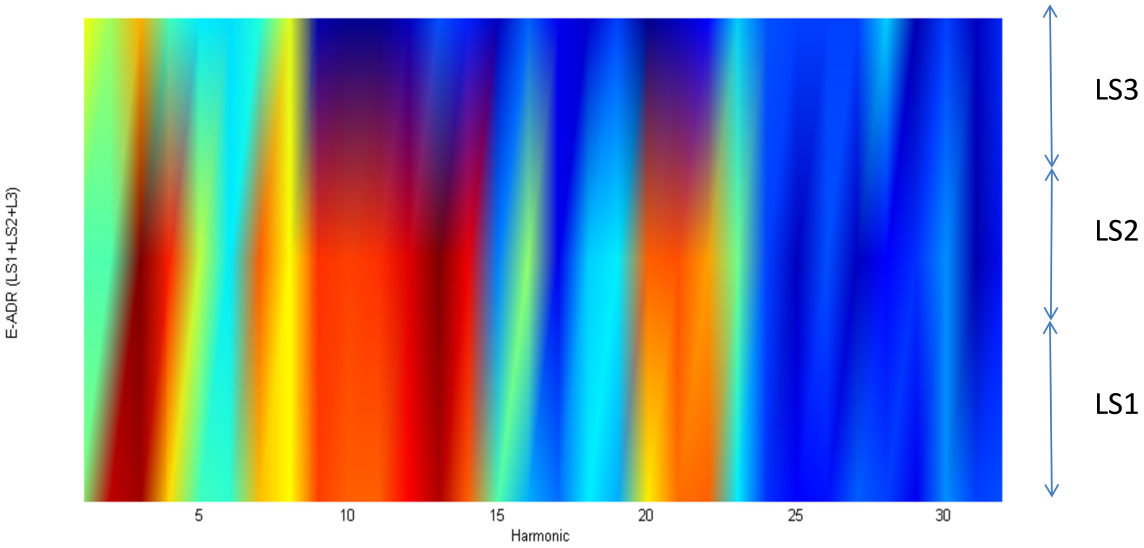


Figure 10. E-*ADR* harmonic energy variation for Limestone samples LS-1, LS-2 and LS-3.

Phase and Spectral Analysis

The phase changes for the Lamproite and Limestone samples are presented in figure 11. This result shows that phase information is unable to categorise the two rock groups, i.e. does not allow them to be distinguishable.

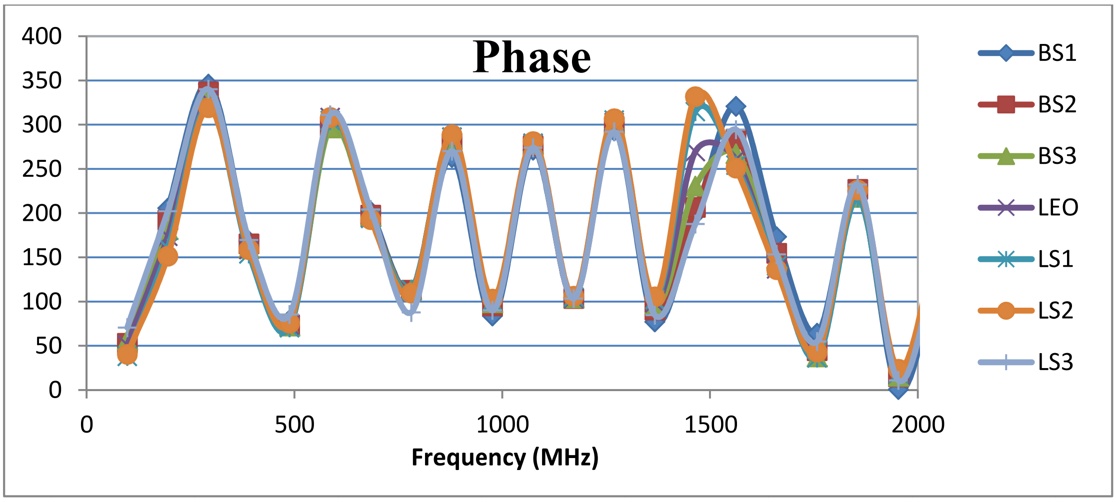


Figure 11. Phase relationship between all 7 samples.

In order to obtain an understanding of the chemical composition of the Lamproite and limestone samples, the spectral data obtained using an *XRF* (X-Ray Fluorescence) spectrometer and Adroks spectral line analysis are reported in figure 12. This comparison shows that the results of the Adrok spectral line analysis are not in agreement with the *XRF* results. It may be concluded that the primary reason of this result is due to the under-representation of certain mineral and elements (for example, Calcium and Silica) and the complete absence of others.

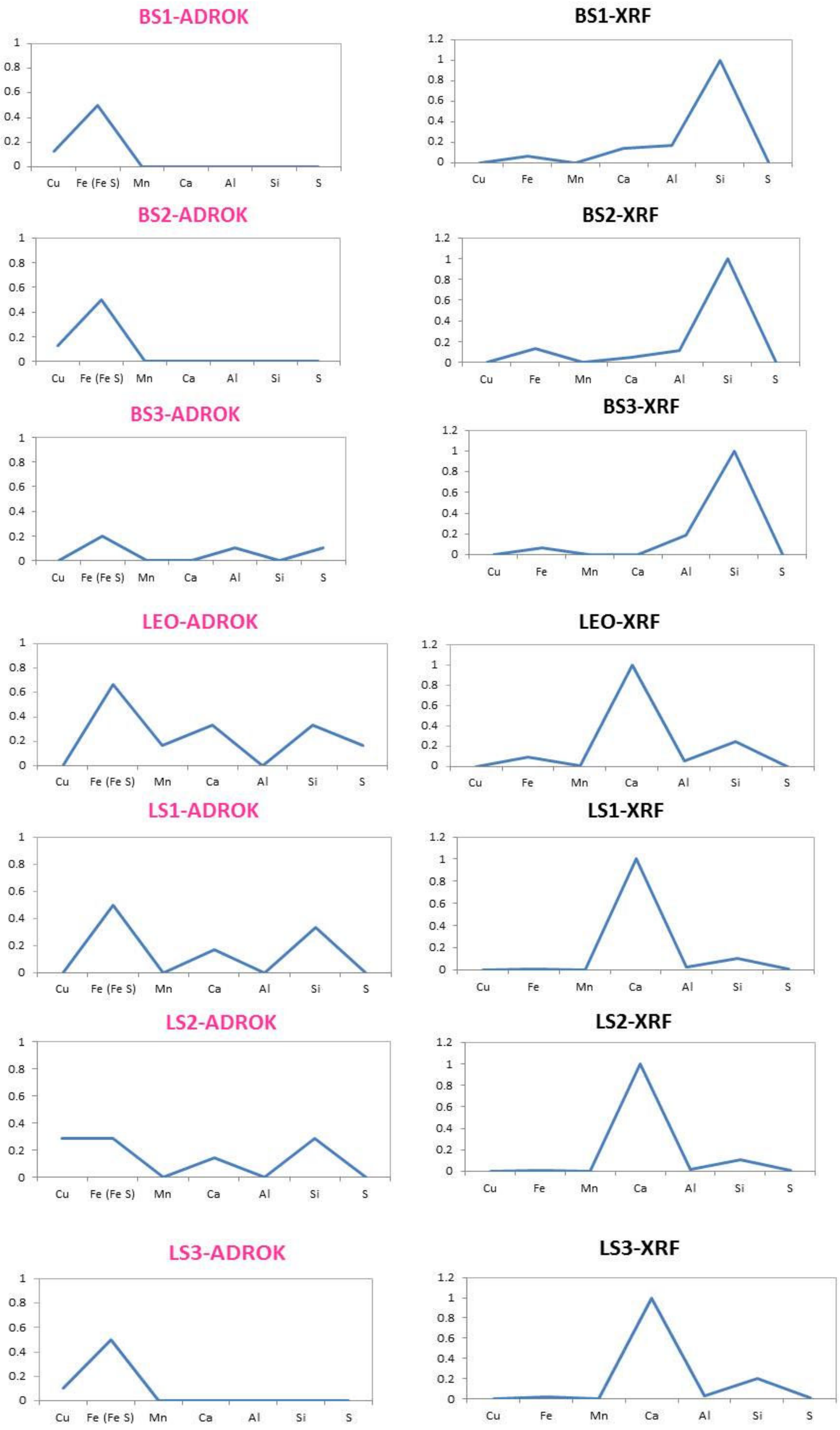


Figure 12. Comparison of Adroks spectral line analysis (left) with that of the results of the XRF analysis (right)

8.0 DISCUSSION

The *ADR* scans enabled the *E-gamma*, *E-Mean* and *E-ADR* to be calculated for the Lamproite and Limestone samples. This data was used to create a false *RGB* image which was presented in figure 7. The *RGB* graph is a visual tool that allows the changes in *E-ADR*, *E-gamma* and *E-mean* to be highlighted. *RGB* graphs represent a 3 coordinate space, whereby, the combination of the coordinates gives a defined colour. In order to obtain this, it was necessary to take an average value for *E-gamma*, *E-Mean* and *E-ADR* for every sample, then find the maximum value for *E-gamma*, *E-Mean* and *E-ADR* respectively, across all samples. Finally, by dividing every averaged value by the maximum value, a normalised value is obtained (these value range from 0 to 1). Once the *E-gamma*, *E-Mean* and *E-ADR* are normalised, this gives a set of 3 numbers that vary from 0 to 1 forming the *RGB* space.

Figure 7 demonstrated the change of *E-gamma* (R-component), *E-Mean* (G-component) and *E-Gamma* (B-component) respectively, for the different rock samples. The strips corresponding to the different samples show different colours, which is due to the different physical and chemical composition of the samples. In particular, it is possible to distinguish a *LEO* (number 4) sample from the limestone and Lamproite samples. The introduction of the more pink shades into the Limestone samples is due to a decrease in value of the green component i.e. the *E-Mean*.

Unfortunately, the results of the phase and spectral analysis were unable to provide distinguishing features. However, additional information can be obtained from the *ADR* harmonic energy variation images. Figures 8, 9 and 10 show the change of the *ADR* harmonic energy for all samples. In particular, figure 8 shows the Harmonic energy variation for the Lamproite samples *BS1*, *BS2*, *BS3*. Figure 9 shows the addition of the Lamproite sample, *LEO*. It is possible to observe that the introduction of *LEO* produces a different energy variation at the ~3rd harmonic and between the 10th and 15th harmonic (both areas have been circled). Figure 10 shows the *ADR* harmonic variation for the limestone samples. In this case, the *ADR* energy variation image is completely different with respect to both the BS lamproites and the *LEO* sample. The *ADR* harmonic Energy variation is an additional parameter that highlights the difference between Limestone and Lamproites samples, as well as identifying a specific harmonic energy pattern for the *LEO* sample.

9.0 CONCLUSIONS

Lamproites and Limestone samples are investigated by using Adrok technology. Energy-*ADR*, Energy-Mean and Energy-Gamma are parameters related to the physical and chemical properties of the rock samples. By using these parameters, (*RGB* image presented in figure 7) the differences between the samples can be highlighted. Harmonic energy *ADR* images reported in figures 8, 9 and 10 gave a specific pattern for the rock samples, in particular, the *LEO* sample showed a distinct energy pattern at the 3rd and between the 10th and the 15th harmonic.

10.0 FUTURE RESEARCH RECOMMENDATIONS

The laboratory results demonstrated that it is possible to observe the difference between Lamproite and Limestone samples. A future step would be to acquire field data which could be compared the laboratory data presented here. Due to the inconclusive results of the phase analysis and poor correlation of spectral data between Adroks spectral analysis and the *XRF* results, it would be strongly recommended that this data is not presented to Diamond exploration Consultancy Pty Ltd. until appropriate additions are made to Adroks spectral library.

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