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Burrup Peninsula Aboriginal Petroglyphs: Colour Change & Spectral Mineralogy 2004–2013

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Executive summary

The Burrup Peninsula is around 30 km long and 6 km wide and is located 1300 km from Perth (Western Australia) and was named after Mount Burrup, the highest topographic point. It was created when an island was connected to the mainland through the construction of a causeway. The peninsula is of unique cultural and archaeological significance as it contains Australia's largest and most important collection of indigenous petroglyphs. Alongside the petroglyphs, the Burrup Peninsula has several large industrial complexes including iron ore, liquefied natural gas production, salt production and fertilisers with one of Australia's largest ports. Since some of the petroglyphs adjoin industrial areas there has been very public concern expressed that the petroglyphs could be damaged by airborne emissions from the industry. In 2002, The Western Australian government established the independent Burrup Rock Art Technical Working Group (BRATWIG) to review the available expertise and oversee the studies that were conducted to establish whether industrial emissions are likely to affect the petroglyphs.

In 2003 the Burrup Rock Art Monitoring Management Committee (BRAMMC) commissioned a number of studies to monitor the petroglyphs. They included air dispersion modelling studies, air quality and microclimate; colour change, dust deposition and accelerated weathering study and mineral spectroscopy. The studies were based on the monitoring of seven sites with two control sites located on the northern Burrup area and the other five located further south on the lower Burrup Peninsula, closer to the industrial areas.

For the last 10 years (2004 to 2013), petroglyphs at seven specially selected sites (chosen under the guidance of indigenous elders) in the Burrup Peninsula were measured using colour and reflectance spectroscopy measurements. Three spots on each engraving and three spots on each background rock were measured in situ using a portable spectrophotometer for colour measurement and a reflectance spectrometer for visible and near infrared spectral analysis. The 2004 spectral study is the baseline dataset that has been used to monitor potential variation during the last 10 years. The Burrup Rock Art Monitoring Program is ongoing and will continue to be performed annually.

The comparison of the colour and spectral data collected and processed for both the Northern (control sites) and Southern sites has shown no consistent trend in an increasing or decreasing direction. For the first 9 years no observed colour contrast change was detected. However, as the project was entering its 10^{th} year, it was appropriate to review the approach to data analysis that was implemented at the outset and has remained in place without significant modification since 2004. Currently, the following analysis for colour measurements has been carried out:

1. Replicate sample data is collected in L*a*b* numerical format.
2. Measurements at a single spot are averaged and reported.
3. Colour difference between background and engraving is calculated and reported year to year and from the current year to the beginning of the study.
4. Annual measurements of the colour difference between background and engraving are plotted and a trend line is reported.

In 2013, analysis of the data as outlined in the 4 points above has been carried out, along with an ANOVA analysis of the control (Northern Sites) and sample (Southern Sites) L*a*b* average measurements. This was undertaken to provide an analysis of variance between the two groups to demonstrate if there was a statistically significant difference between the groups. To increase the accuracy of future statistical analysis of measurements, a fourth engraving and background spot was analysed on each petroglyph in 2013.

The initial measurements (2004 to 2008) were acquired using only a BYK spectrophotometer. The instrument is described in the experimental section of this report. In 2009 some of the automated memory retention functions of the BYK spectrophotometer started failing, requiring laborious manual data saving. Calibration and instrument performance were unaffected. It was decided to pair the BYK instrument with a more modern Konica Minolta (KM) spectrophotometer (also described in this report) and perform measurements using both instruments to explore the possibility of substituting instruments. Since 2009, each site has been measured in duplicate using the two instruments. A previous report (Alexander, 2013) describes the correlation between L*, a* and b* colour measurements obtained between the 2 instruments and the possibility of replacing the BYK by the KM spectrophotometer altogether for field measurements. Previous analysis shows broad consistency between the measurements obtained by the two instruments, but at times some discrepancies were observed. Acceptance was received from BRATWIG to collect all future measurements using the KM spectrophotometer, and 2013 this spectrophotometer was used to collect all data. The data for previous years collected by the BYK spectrophotometer (2004 -2008) has had a conversion algorithm applied to convert into values that can be compared with the KM data (2009 – 2013).

For the Spectral Mineralogy analysis of the petroglyphs, replicate sample data was collected in spectral format and annual averaged measurements at a single spot are reported in an overlaid plot, as in previous reports, along with a PCA multivariate analysis performed on averaged annual measurements. This analysis was intended to demonstrate whether a systematic change was observed from year to year. Each spot is analysed and plotted individually.

The comparison of the colour and spectral data collected and processed for both the Northern (control sites) and Southern sites shows no consistent trend in an increasing or decreasing direction. For the last 10 years no observed accelerated colour contrast change was detected at the Southern test sites, when compared with the Northern control sites.

1. Introduction

In response to tender number 34DIR0603 issued by the former WA Department of Industry and Resources and more recently under contract with the Department of Environment and Conservation (#DEC6210022011), CSIRO Materials Science and Engineering (CMSE) has measured the colour of selected petroglyphs on the Burrup Peninsula over a period of nine years. The requirements stipulated by the project were the measurement of re-identifiable sample points on petroglyphs annually for the measurement period.

For the last 10 years (2004 to 2013 - Ramanaidou and Caccetta, 2005; Ramanaidou and Wells 2006; Ramanaidou *et al*., 2007; Ramanaidou, et al., 2009a; Ramanaidou et al., 2009b; Lau et al., 2010; Lau et al., 2011; Lau et al., 2012; Lau et al., 2013), the petroglyphs at 7 specially selected sites in the Burrup Peninsula (Western Australia) were measured using reflectance spectroscopy and colour spectrophotometry. Three spots on each engraving and 3 spots on each background rock were measured *in situ* using an ASD spectrometer and a spectrophotometer[1]. The spectral measurements were co-located with the colour measurements acquired simultaneously. For each engraving and background spot, seven spectra were acquired and averaged. The spectral variation for each spot (both engraving and background) was also assessed. The colour values were crosschecked to the colour value calculated by the ASD spectrometer.

The 2004 spectral study (Ramanaidou and Caccetta, 2005) is the baseline dataset that has been used to monitor potential variation that occurred in the last 10 years. The ten-year study (2004-2013) has assessed the mineralogy to monitor and explain the mineralogical changes (if any) of seven rock art sites in the Burrup Peninsula, along with analysing any colour differences or changes.

[1] A forth engraving and background spot was analysed in the 2013 field data collection.

2. Location and sampling of the petroglyphs

The sites for monitoring (Table 1 and Figure 1) were determined by the BRAMMC Rock Art Management Committee, and the final decision for a representative petroglyph at each site (each site contains one or more petroglyphs) was determined in consultation with the Committee's Technical Advisor and nominated representatives of the local indigenous communities including members of Murujuga Aboriginal Corporation. Respecting the cultural laws of the traditional owners for the entitlement of access, the selected petroglyphs were firstly evaluated for their suitability for scientific study, including aspect (e.g. elevation and direction of exposure).

Initially, three sampling 'spots' on each selected petroglyph were identified, and in each spot two areas were monitored (i.e. six sampling points per petroglyph):

An area classified as 'engraving' – defined by the graffito lines or pecking marks that constitute the image.

An area classified as 'background' – a section of the adjacent rock surface unmarked by the petroglyph.

For spectral mineralogy, measurements based on the average of a minimum of seven readings were recorded at each sampling point. 21 replicate measurements were made for colour analysis.

To increase the accuracy of statistical analysis of measurements, a fourth engraving and background spot was analysed on each petroglyph in 2013.

A sampling area was chosen on the criteria that it had relatively uniform colour over a minimum area of 20 mm, so that comparative measurements could be made between the photo spectrometer and the reflectance spectroscopy.

Table 1: Details of the sites for colour and spectral mineralogy measurements (site 3 is not included in this study)

Site	Site name	Coordinates (GDA 94, Zone 50)	
1	Dolphin Island	484,975	7,738,503
2	Gidley Island	482,166	7,740,857
4	Woodside	477,398	7,721,980
5	Burrup Rd	475,959	7,719,771
6	Water Tanks	477,698	7,720,137
7	Deep Gorge	477,956	7,717,987
8	King Bay South	474,082	7,717,229

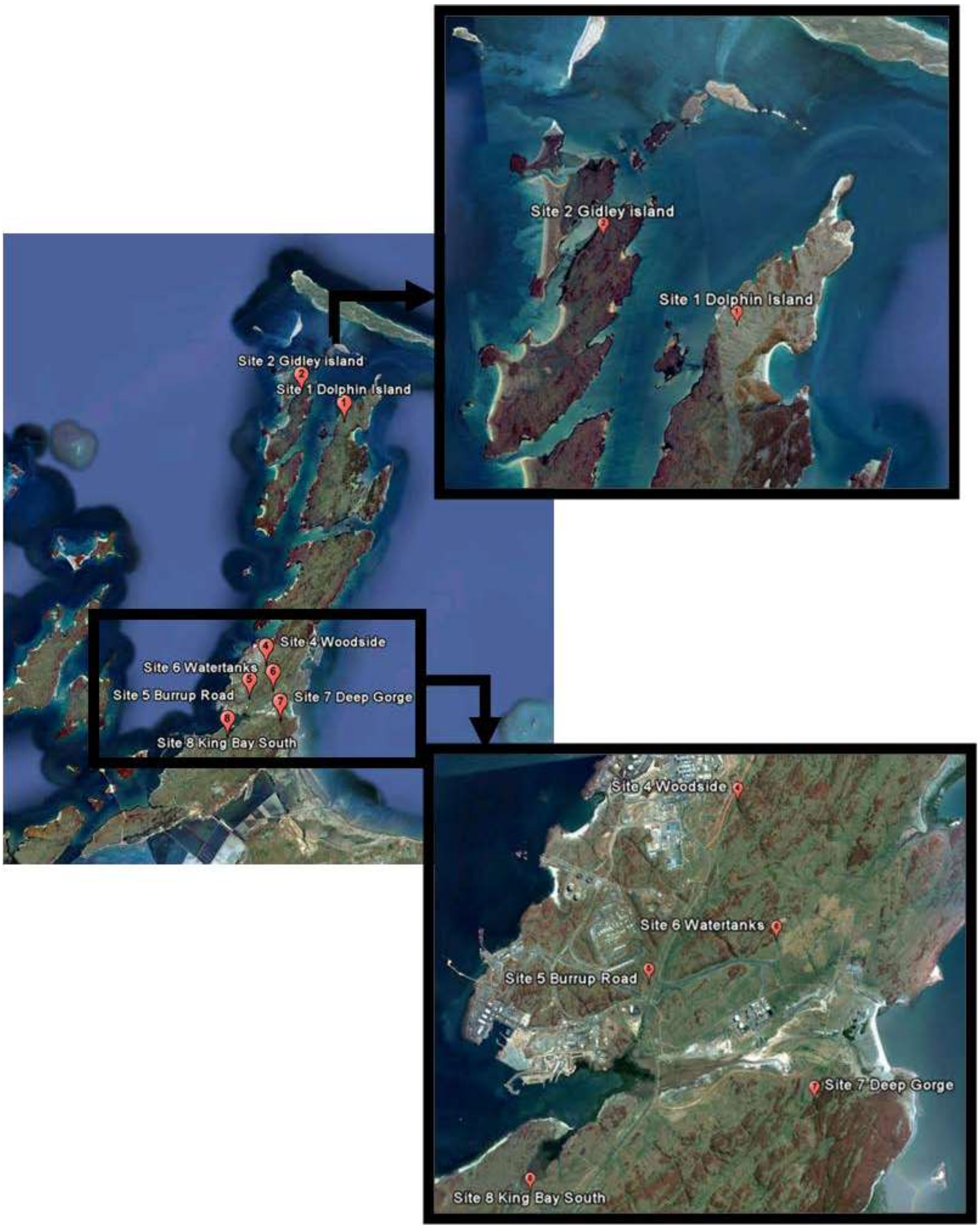


Figure 1: Google Earth® maps of the Burrup Peninsula with the location of the petroglyphs.

Sites 1 and 7 consist of gabbros whereas the rest of the sites are granophyres. Gabbro is dark, coarse-grained, intrusive mafic igneous rocks with 45-52% SiO_2 (Table 2). Granophyre is a subvolcanic rock that contains quartz and alkali feldspar in characteristic angular intergrowths. Granophyres are intrusive rocks with a chemical composition similar to those of granites (Table 2) occurring within layered igneous intrusions dominated by gabbro.

Table 2: Classification of igneous rocks

Type	Ultramafic <45% SiO_2	Mafic 45-52% SiO_2	Intermediate 52-63% SiO_2	Intermediate-Felsic 63-69% SiO_2	Felsic<45% SiO2 >69%SiO_2
Volcanic Rocks	Komatiite	Basalt	Andesite	Dacite	Rhyolite
Sub-Volcanic Rocks	Picrite	Dolerite			Pegmatite
Plutonic Rocks	Kimberlite, Lamproite, Peridotite	**Gabbro**	Diorite	Granodiorite	**Granite**

The primary minerals forming fresh granophyres include: quartz and potash feldspar. The primary minerals forming fresh gabbro include: calcium feldspar; pyroxene; epidote; and chlorite. The primary minerals forming minor magnetite are apatite, sphene and rutile.

3. Colour Measurement

3.1 Introduction

Portable, hand-held spectrophotometry was identified as a suitable technique. It has been recognised as a repeatable way of recording colour in units of standard CIE chromaticity coordinates in many contexts, including archaeological situations (Mirti, 2004). CIE chromaticity coordinates are an internationally recognised numerical system of permanently and objectively describing the colour of a surface or material as a point in three-dimensional L*a*b* colour space (L* - degree of lightness, a* - degree of red/green, b* - degree of yellow/blue), identifying a tristimulus value (L*a*b*) for each sample point.

In situ monitoring of degradative change through colour measurement has been reported by Mirmehdi *et al.* (2001), who undertook a pilot study designed for monitoring and modelling the deterioration of paint residues in a cave environment through digital image comparisons with a reference image. The template-matching technique was considered unsuitable and impractical for the Burrup study for two reasons:

a) Template matching, as described by Mirmehdi *et al.* (2001), would require the collection of digital images with repeatable and controlled spectral illumination, angle of incidence and collection. Burrup petroglyphs are located in remote, exposed locations, and it would not be possible to control the colour, temperature and angle of the ambient lighting easily without blocking all the ambient daylight, or collecting images at night with the ambient moon and starlight removed.

b) The effect of metamerism in relation to the reference template and rock surface has not been accounted for. It is well known that surfaces appearing similar in colour under one set of illumination conditions can appear dramatically different with another spectral illuminant or angle of incidence. The reference template is a glossy (laminated) smooth surface, while the rocks in this study are significantly rougher.

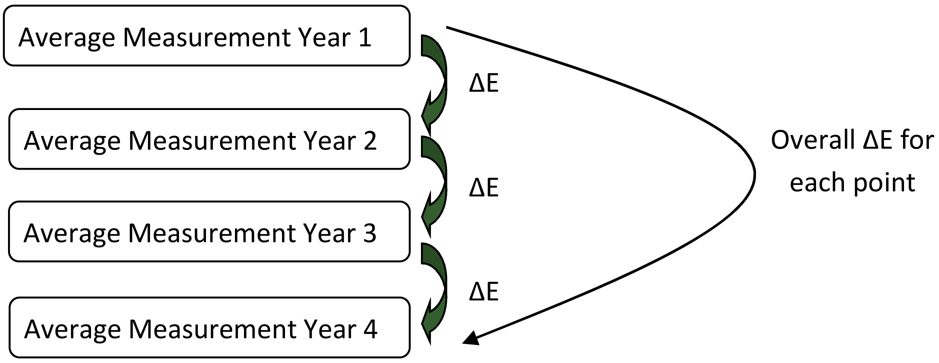
3.2 Experimental Methodology

The difference between two colours measured instrumentally is ΔE. It derives from the German word – *Empfindung* – which means a difference in sensation. A ΔE value of zero represents an exact match. It is the standard CIE colour difference method, and measures the distance between the two colours, calculated in 3D L*a*b* colour space. In this way, colour difference can be evaluated through measuring the tristimulus values of points over time, and calculating ΔE to evaluate the colour difference with time. This enabled the colour contrast between an engraving and a rock surface to be monitored to evaluate whether it is decreasing.

The difference between two colours, ΔE, can be evaluated using the 1976 CIE colour difference formula (Hunter, 1987). In CIE L*a*b* space, the difference is:

$$\Delta E^*Lab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$$

This was used to evaluate the colour change of single points between consecutive years over which the monitoring occurred, viz.:



The original instrument used for colour measurement was a portable spectrophotometer (BYK-Gardner[2]) with inbuilt spectral illuminants: CIE illuminant A, D65 and F2 (see Figure 2 and Table 3). A CIE standard illuminant represents an aimed spectral power distribution of a theoretical real light source. For example, CIE illuminant A is a mathematical representation of tungsten halogen (incandescent), and CIE illuminant D65 is a mathematical representation of a phase of daylight, recommended by the CIE if daylight is of interest. F illuminants are similar to fluorescent light sources.

It is essential to use an artificial light source for reproducibility and determination of colour change, as the fluctuations in the natural daylight spectrum due to time of day, season and weather means naturally illuminated measurements would be inconsistent and unreliable.

The geometry of the measuring head on the spectrophotometer is designed to exclude light on flat surfaces. However, as rock surfaces are not always flat, a collar of black fabric was used when necessary for the complete exclusion of natural light.

Figure 2: Portable spectrophotometer used for colour measurements.

[2] Spectrophotometer website: http://www.bykgardner.com/englisch/products.php?lv3=2.

Table 3: Portable spectrophotometer specifications

Repeatability	Inter-Instrument Agreement	Color System	Color Differences	Indices	Spectral Interval
0.01 ΛE, 1σ	0.02 ΛE, 1σ	CIELab/Ch; Lab(h); XYZ; Yxy; RxRyRz	ΛE; ΛE(h); ΛEFMC2; ΛE94; ΛECMC; Component differences	YIE313; YID1925; WIE313; CIE; Berger; Color strength; Opacity; Metamerism	20 nm
Observer	**Language**	**Power Supply**	**Operating Temperature**	**Illuminants**	**Spectral Range**
2º; 10º	English; German; French; Italian; Spanish; Japanese	4 AA alkaline; NiCd or MH	50 to -110 ºF (10 to -42 ºC)	A; C; D50; D55; D65; F2; F6; F7; F8; F10; F11	400 - 700 nm
Geometry	**Aperture**	**Humidity**			
45/0	4 mm	< 85% relative humidity, non-condensing / 35 ºC (95 ºF)			

In 2009, a Konica Minolta CM-700d spectrophotometer was used during the field data collection trips to evaluate its suitability and practical handling features, and was found to be reliable and well suited to the purpose. The spectrophotometer has a flat conical head configuration which provided an improved repeatability on the rougher rock surfaces (Figure 3). The measurement head has a diameter of 10 mm which corresponds with the instrument used in parallel for spectral mineralogy measurements (ASD FieldSpec Pro). The increased measurement field diameter reduces the effect of surface heterogeneity on the overall averaged colour measurement. The instrument specifications are given in Table 4. A comparison of measurements obtained by the two instruments on rock surfaces is presented in Table 5.

Figure 3: Konica Minolta CM-700d spectrophotometer.

Table 4: Instrument Specifications for the Konica Minolta CM-700d spectrophotometer.

Colour Space L*a*b*	**Observer** 10^{O}	**Illuminant** D65 –simulated daylight	**Measurement/ illumination area** SAV: Φ3 mm/Φ6 mm
Light source Pulsed xenon lamp (with UV cut filter)	**Measurement time** Approx. 1 second	**Repeatability** Spectral reflectance: Standard deviation within 0.1%	

Table 5: Comparison of BYK and Konica spectrophotometer measurements on rock surfaces

	Greyish Surface				Smooth Red Surface				Rough Red Surface		
Konica	*L*(D65)*	*a*(D65)*	*b*(D65)*		*L*(D65)*	*a*(D65)*	*b*(D65)*		*L*(D65)*	*a*(D65)*	*b*(D65)*
	41.44	11.85	19.51		38.14	18.23	18.30		40.06	13.69	19.33
	41.44	11.85	19.51		38.61	16.78	17.20		39.36	13.49	19.18
	41.54	10.84	18.59		38.29	18.03	18.37		39.65	13.53	19.23
	40.86	11.45	19.08		38.50	18.82	18.68		39.52	13.55	19.27
	40.86	11.45	19.08		36.45	16.65	16.19		39.78	13.29	18.53
	40.87	11.46	19.07		39.46	17.69	18.12		39.17	13.53	19.08
	41.18	11.71	19.30		37.47	17.54	17.66		39.31	13.58	19.23
	41.18	11.70	19.31		38.85	17.32	17.77		40.80	13.91	19.36
	41.58	11.10	18.85		40.95	19.58	19.53		39.34	13.32	18.80
	41.62	11.11	18.87		41.57	19.73	20.01		39.10	13.26	18.69
	41.47	11.64	19.35		41.61	20.44	20.12		38.96	13.82	19.57
	41.43	11.62	19.33		42.19	21.17	21.11		39.60	13.47	19.14
	41.01	11.25	18.98		39.02	17.15	17.65		40.05	13.57	19.15
Av	**41.27**	**11.46**	**19.14**	**Av**	**39.32**	**18.39**	**18.52**	**Av**	**39.59**	**13.54**	**19.12**
Stdev	**0.29**	**0.31**	**0.27**	**Stdev**	**1.75**	**1.44**	**1.35**	**Stdev**	**0.50**	**0.19**	**0.29**

BYK	21.59	11.57	15.94		37.66	15.81	15.25		28.04	8.41	8.36
	24.45	8.58	17.25		35.81	13.84	12.9		39.19	6.21	5.13
	25.36	10.93	16.81		39.51	17.51	16.22		31.24	8.82	10.33
	36.03	10.78	19.74		33.86	14.66	13.66		33.30	9.39	13.25
	36.97	11.22	20.99		39.87	17.98	16.98		28.07	9.48	12.41
	32.30	9.53	18.35		38.4	17.08	16.48		27.39	8.38	10.17
	30.97	9.19	17.12		37.15	15.37	14.67		27.61	8.24	9.49
	38.94	11.19	14.78		36.99	15.82	14.92		23.08	7.84	9.00
	26.11	9.44	17.87		38.45	16.35	15.83		27.98	9.87	12.02
	22.48	8.53	17.22		39.49	17.85	16.99		31.06	8.22	10.55
	29.70	9.65	17.54		37.6	17.36	18.77		30.53	9.96	12.36
	26.18	11.89	11.20		37.2	17.69	19.76		39.84	6.06	6.63
	30.54	9.82	13.44		37.33	16.8	18.08		31.70	9.76	13.15
Av	**29.36**	**10.18**	**16.79**	**Av**	**37.64**	**16.47**	**16.19**		**30.69**	**8.51**	**10.22**
Stdev	**5.59**	**1.14**	**2.55**	**Stdev**	**1.63**	**1.30**	**1.97**		**4.69**	**1.27**	**2.50**

The numerical value of the measurement is slightly different which is to be expected given the measurement angle may be altered due to the head configuration.

The overall variance is significantly reduced using the Konica instrument. It is less effective at reducing the variance when it is already low using the BYK instrument, which can be observed in measurements from the smooth red surface.

The ability to discern colour change on the rock surfaces is very much dependent on demonstrated differences in measurement, and a reduction in variance is a critical factor for achieving this. Colour measurements were collected by both the BYK and Konica Minolta spectrophotometers for the years 2009 – 2013, allowing a conversion factor to be determined that can be applied to BYK data collected from 2004 to 2008 so it is comparable to data collected by the Konica Minolta spectrophotometer from 2009 onwards. The BYK spectrophotometer has increasingly become electronically unreliable. While this has not affected the quality of the colour measurements, it has prevented the instrument from saving data as required and necessitates impractical measures of manual data recording, coupled with excessive and repeated data saving and transfer to ensure confidence the data will not be lost. Given these difficulties, coupled with the planarity of the measurement surface in the Konica Minolta spectrophotometer contributing to a reduction variance, all measurements in 2013 were collected using the Konica Minolta spectrophotometer. For the results presented in this report, years 2009 - 2013 were collected using the KM spectrophotometer, while 2004 -2008 were BYK spectrophotometer data corrected to be comparable with the new instrumentation.

3.3 Results and Discussion

3.3.1 YEAR TO YEAR COLOUR DIFFERENCES

The following pages present photographs of the monitored petroglyphs at each site, showing the sampling points of engravings and background rock, and the average colour measurements that were recorded at these points each year. The new 4th engraving and background analysis spots are indicated in these photos.

The original data collection in 2004 consisted of an average of seven colour measurements (L*a*b*) at each sample point. However, when in the field, it became apparent that additional measurements would be useful to statistically evaluate the variability of measurements. In the second year of colour measurements, 21 independent measurements were taken at each sample point (3 times the originally intended 7 measurements) to reduce sample variance introduced by surface heterogeneity or roughness, and by systematic error. For clarity, the raw data has not been included here, but averages of the data are presented with the colour difference measurements calculated with the standard CIE methods.

Figure 4: Site 1- Dolphin Island.

Table 6: Average Colour Measurements for Site 1 – Dolphin Island (2004 – 2013).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 1 Spot 1 Engraving				
Average 2013	42.93	9.35	16.41	0.88
Average 2012	42.76	9.79	17.15	0.38
Average 2011	42.42	9.83	17.32	0.48
Average 2010	42.85	9.74	17.13	1.48
Average 2009	41.76	9.22	16.28	17.37
Average 2008	29.76	-1.57	9.85	2.09
Average 2007	29.35	0.47	9.89	3.28
Average 2006	29.27	-2.81	9.81	3.95
Average 2005	28.88	1.12	9.86	3.50
Average 2004	28.73	4.61	9.88	
Site 1 Spot 1 Background				
Average 2013	32.55	11.17	9.87	0.45
Average 2012	33.00	11.21	9.81	0.89
Average 2011	32.82	10.34	9.75	1.47
Average 2010	33.78	11.18	10.48	0.60
Average 2009	33.44	10.87	10.08	1.70
Average 2008	32.09	9.89	9.79	0.80
Average 2007	31.73	9.17	9.78	0.72
Average 2006	31.89	8.47	9.74	1.72
Average 2005	31.61	10.16	9.78	0.49
Average 2004	32.08	10.06	9.76	
Site 1 Spot 2 Engraving				
Average 2013	32.26	15.71	16.24	1.37
Average 2012	33.14	16.23	17.16	1.20
Average 2010	33.81	16.77	17.99	2.39
Average 2010	32.28	15.91	16.37	1.58
Average 2009	33.24	16.54	17.46	10.89
Average 2008	28.87	10.01	9.91	2.54
Average 2007	28.26	7.55	9.83	2.82
Average 2006	27.45	4.85	9.68	2.83
Average 2005	27.35	7.68	9.72	0.40
Average 2004	27.47	7.30	9.70	
Site 1 Spot 2 Background				
Average 2013	30.34	8.39	8.72	4.85
Average 2012	32.41	11.62	11.68	3.84
Average 2011	30.37	8.97	9.79	2.59
Average 2010	32.05	10.65	10.83	1.72
Average 2009	31.76	9.64	9.47	2.59
Average 2008	31.33	7.11	9.80	4.44
Average 2007	30.17	2.83	9.71	5.76
Average 2006	31.86	8.33	9.78	2.14
Average 2005	30.17	7.02	9.80	2.12
Average 2004	31.61	8.58	9.82	

Site 1 Spot 3 Engraving				
Average 2013	38.87	13.83	18.18	1.15
Average 2012	37.79	13.99	17.81	1.51
Average 2011	39.11	14.08	18.54	0.79
Average 2010	38.53	14.36	19.00	1.29
Average 2009	39.81	14.52	19.06	12.25
Average 2008	32.75	9.98	10.14	2.19
Average 2007	31.41	8.25	10.10	1.18
Average 2006	30.65	9.16	10.07	2.78
Average 2005	31.18	11.89	10.13	0.69
Average 2004	31.83	11.67	10.12	0.00
Site 1 Spot 3 Background				
Average 2013	29.17	12.25	12.36	4.22
Average 2012	30.21	9.47	9.36	1.77
Average 2011	30.14	10.67	10.67	0.52
Average 2010	29.75	10.44	10.40	0.26
Average 2009	29.97	10.57	10.42	7.12
Average 2008	28.91	3.56	9.72	2.74
Average 2007	29.76	6.17	9.76	3.19
Average 2006	28.47	3.25	9.68	2.56
Average 2005	28.12	5.79	9.74	1.41
Average 2004	28.54	4.44	9.67	0.00
Site 1 Spot 4 Engraving				
Average 2013	38.39	13.95	18.56	
Site 1 Spot 4 Background				
Average 2013	29.49	11.17	10.91	

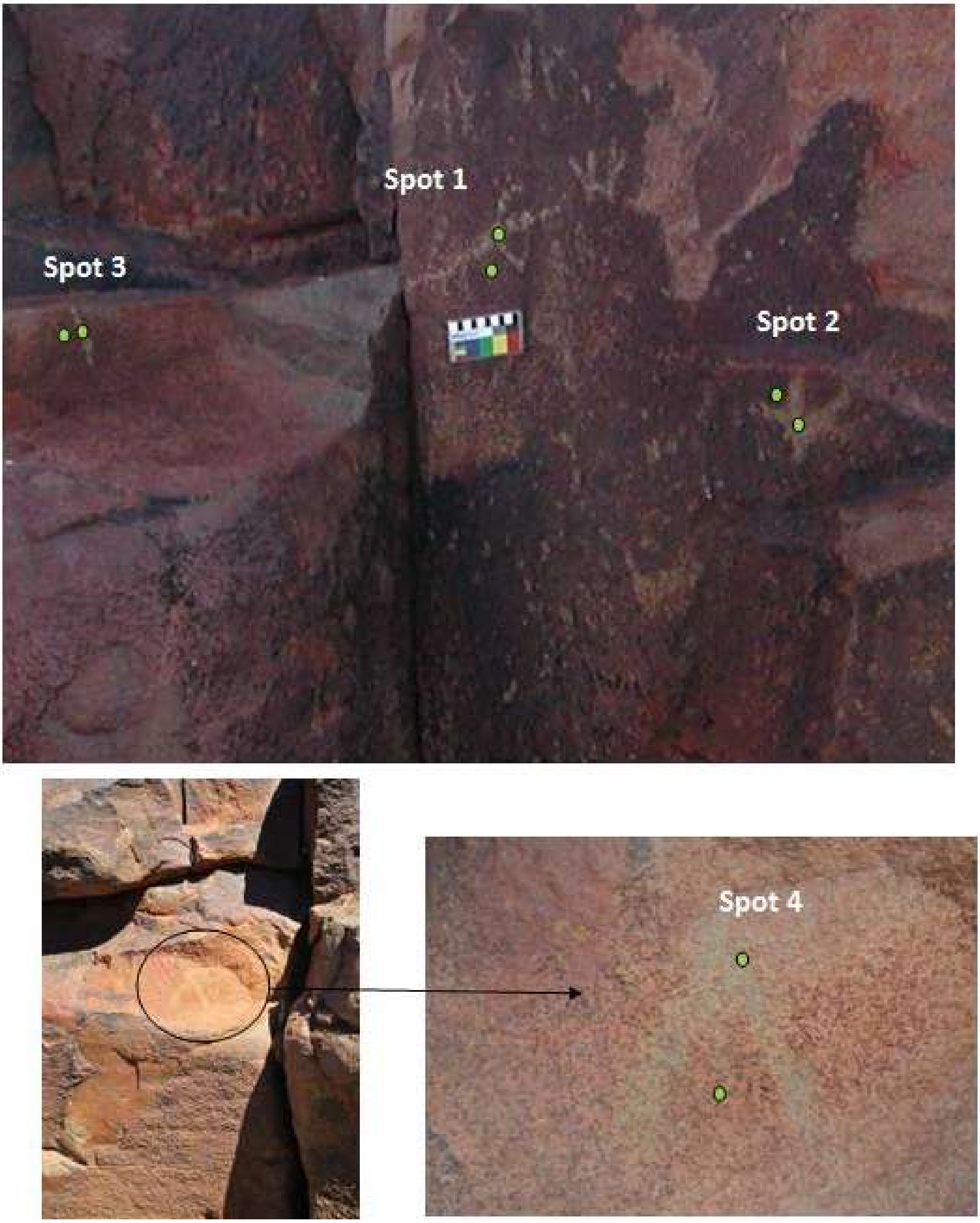


Figure 5: Site 2 – Gidley Island.

Table 7: Average Colour Measurements for Site 2 – Gidley Island (2004 – 2013).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 2 Spot 1 Engraving				
Average 2013	40.17	9.06	16.98	0.40
Average 2012	39.83	9.22	16.83	3.25
Average 2011	42.78	9.31	18.20	0.35
Average 2010	43.06	9.44	18.37	4.54
Average 2009	38.80	9.33	16.81	11.11
Average 2008	32.76	2.92	10.05	0.71
Average 2007	32.34	3.49	9.99	0.90
Average 2006	33.00	4.11	10.11	2.57
Average 2005	32.88	6.68	10.13	0.65
Average 2004	32.52	6.14	10.05	0.00
Site 2 Spot 1 Background				
Average 2013	31.68	10.04	11.76	1.30
Average 2012	30.53	9.96	11.16	1.23
Average 2011	31.65	10.36	11.47	1.68
Average 2010	32.33	10.41	13.01	1.76
Average 2009	31.44	9.88	11.58	3.24
Average 2008	31.88	7.15	9.90	2.90
Average 2007	31.13	4.35	9.77	2.16
Average 2006	31.37	6.50	9.82	1.27
Average 2005	31.47	7.76	9.93	1.82
Average 2004	30.50	6.22	9.90	0.00
Site 2 Spot 2 Engraving				
Average 2013	43.89	11.96	20.80	0.85
Average 2012	44.14	11.19	20.52	0.43
Average 2011	44.44	10.99	20.76	0.79
Average 2010	44.68	11.58	21.24	1.27
Average 2009	45.12	12.68	21.68	17.64
Average 2008	33.16	6.53	10.26	1.17
Average 2007	32.95	7.69	10.25	1.27
Average 2006	33.00	6.42	10.24	2.72
Average 2005	32.98	9.14	10.28	1.11
Average 2004	32.33	8.23	10.21	0.00
Site 2 Spot 2 Background				
Average 2013	28.72	10.14	9.96	1.34
Average 2012	29.60	10.55	10.89	1.03
Average 2011	28.86	11.27	10.88	0.53
Average 2010	29.37	11.26	11.01	1.40
Average 2009	29.80	12.46	11.60	3.22
Average 2008	31.45	10.33	9.84	1.10
Average 2007	31.28	9.24	9.76	1.34
Average 2006	31.46	10.57	9.80	2.13
Average 2005	31.34	12.69	9.89	3.39
Average 2004	31.21	9.31	9.78	0.00

Site 2 Spot 3 Engraving				
Average 2013	39.50	11.63	19.31	1.69
Average 2012	41.07	12.02	19.81	2.19
Average 2011	42.79	10.67	19.83	3.25
Average 2010	40.16	12.56	20.13	3.62
Average 2009	43.29	10.74	19.94	15.36
Average 2008	31.87	7.39	10.22	1.69
Average 2007	33.52	7.06	10.25	2.46
Average 2006	32.77	9.39	10.27	0.46
Average 2005	32.81	8.94	10.23	1.19
Average 2004	31.61	8.95	10.20	0.00
Site 2 Spot 3 Background				
Average 2013	30.21	12.54	16.33	0.58
Average 2012	29.67	12.63	16.16	1.38
Average 2011	30.88	12.85	16.79	1.26
Average 2010	31.72	13.52	17.46	1.19
Average 2009	30.85	13.06	16.78	7.20
Average 2008	30.25	10.66	10.02	5.01
Average 2007	29.12	5.78	9.86	2.61
Average 2006	29.06	8.39	9.98	4.25
Average 2005	30.26	12.46	10.10	0.80
Average 2004	29.70	11.89	10.06	0.00
Site 2 Spot 4 Engraving				
Average 2013	41.73	14.62	21.63	
Site 2 Spot 4 Background				
Average 2013	38.12	20.61	22.72	

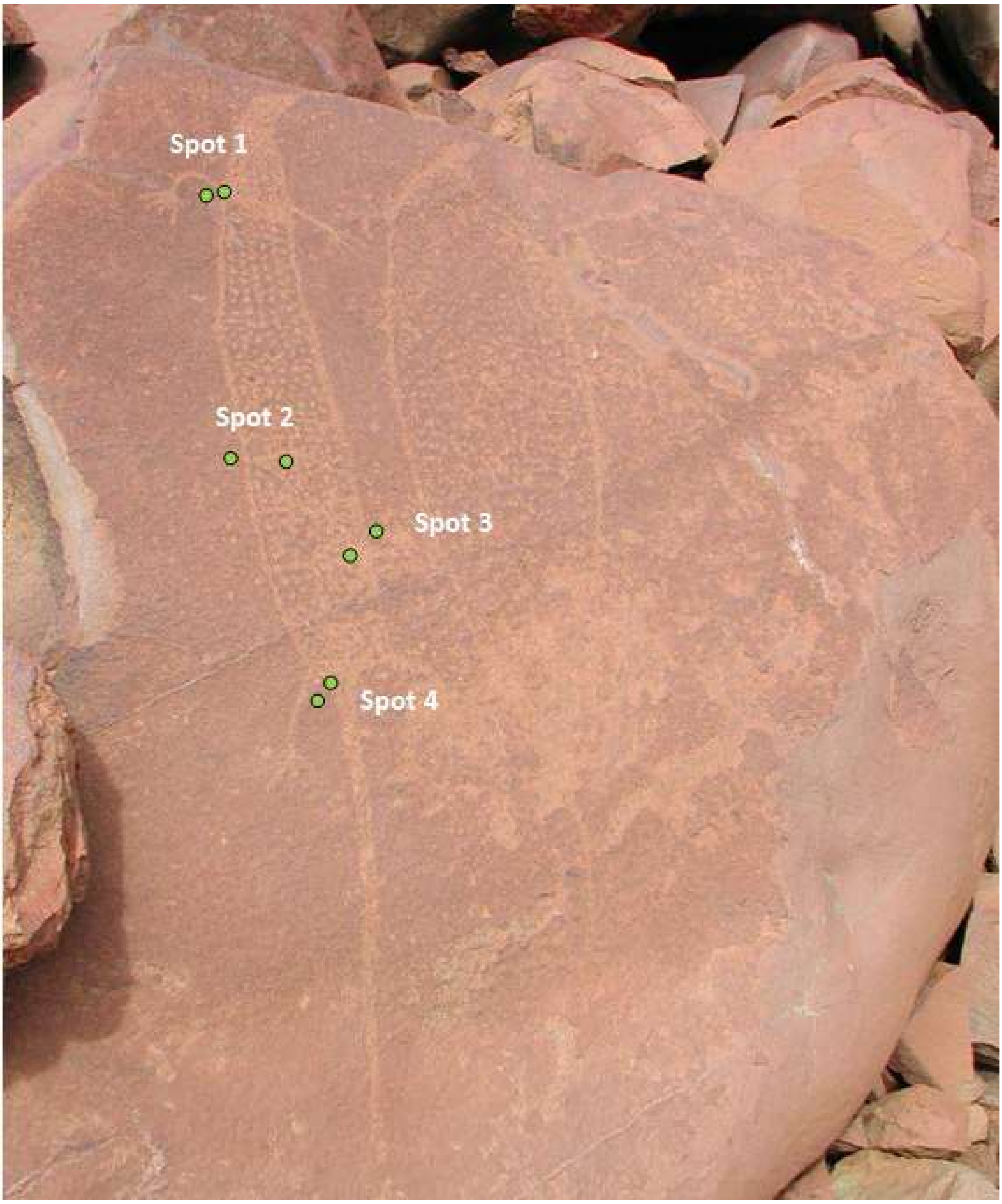


Figure 6: Site 4 – Woodside.

Table 8: Average Colour Measurements for Site 4 – Woodside (2004 – 2013).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 4 Spot 1 Engraving				
Average 2013	34.34	16.21	18.99	0.74
Average 2012	34.10	15.89	18.37	0.84
Average 2011	34.20	16.31	19.09	0.28
Average 2010	34.33	16.12	18.93	4.10
Average 2009	38.09	16.75	20.46	12.88
Average 2008	31.21	13.26	10.15	1.03
Average 2007	31.16	14.29	10.17	0.96
Average 2006	31.11	13.33	10.16	2.13
Average 2005	30.66	15.41	10.18	0.75
Average 2004	30.54	14.67	10.13	0.00
Site 4 Spot 1 Background				
Average 2013	30.01	13.52	14.11	0.65
Average 2012	30.57	13.68	14.39	0.30
Average 2011	30.37	13.89	14.48	0.43
Average 2010	30.77	13.81	14.60	3.03
Average 2009	33.53	14.64	15.53	8.17
Average 2008	30.33	9.66	9.90	0.52
Average 2007	29.81	9.68	9.90	0.40
Average 2006	30.11	9.94	9.93	2.42
Average 2005	29.79	12.34	9.94	0.80
Average 2004	29.98	11.56	9.91	0.00
Site 4 Spot 2 Engraving				
Average 2013	33.33	15.16	18.23	0.64
Average 2012	32.69	15.25	18.31	1.40
Average 2011	33.94	15.89	18.34	0.57
Average 2010	33.90	15.66	17.83	0.66
Average 2009	34.55	15.74	17.82	10.74
Average 2008	30.04	9.92	10.01	1.21
Average 2007	29.12	9.14	9.95	1.04
Average 2006	28.77	8.16	9.92	3.16
Average 2005	28.78	11.32	10.00	1.85
Average 2004	28.79	9.46	9.96	0.00
Site 4 Spot 2 Background				
Average 2013	32.69	14.17	15.05	0.65
Average 2012	32.39	14.58	15.47	0.77
Average 2011	31.68	14.39	15.24	1.88
Average 2010	33.19	14.90	16.24	1.65
Average 2009	32.34	14.33	14.95	5.43
Average 2008	31.26	12.30	10.02	0.38
Average 2007	30.91	12.44	9.96	1.74
Average 2006	31.63	14.02	10.02	0.47
Average 2005	31.31	14.36	10.06	0.43
Average 2004	31.36	14.79	10.06	0.00

Site 4 Spot 3 Engraving				
Average 2013	37.39	16.75	20.51	0.67
Average 2012	36.93	16.42	20.17	0.51
Average 2011	37.11	16.78	20.49	0.56
Average 2010	36.89	16.57	20.02	2.75
Average 2009	34.67	15.84	18.57	9.83
Average 2008	30.93	12.35	10.16	1.48
Average 2007	29.89	11.30	10.09	1.35
Average 2006	30.89	12.22	10.17	3.60
Average 2005	30.70	15.81	10.24	1.44
Average 2004	30.48	14.39	10.17	0.00
Site 4 Spot 3 Background				
Average 2013	33.14	14.63	15.78	1.40
Average 2012	32.10	13.99	15.10	5.15
Average 2011	31.55	13.41	10.01	7.04
Average 2010	33.53	14.97	16.58	3.98
Average 2009	30.84	13.47	14.06	4.18
Average 2008	31.21	12.55	10.00	2.25
Average 2007	31.65	14.75	10.07	1.38
Average 2006	31.84	13.38	9.98	1.49
Average 2005	31.10	14.67	10.09	0.96
Average 2004	31.32	13.73	10.00	0.00
Site 4 Spot 4 Engraving				
Average 2013	36.32	16.23	19.70	
Site 4 Spot 4 Background				
Average 2013	31.86	14.28	15.49	

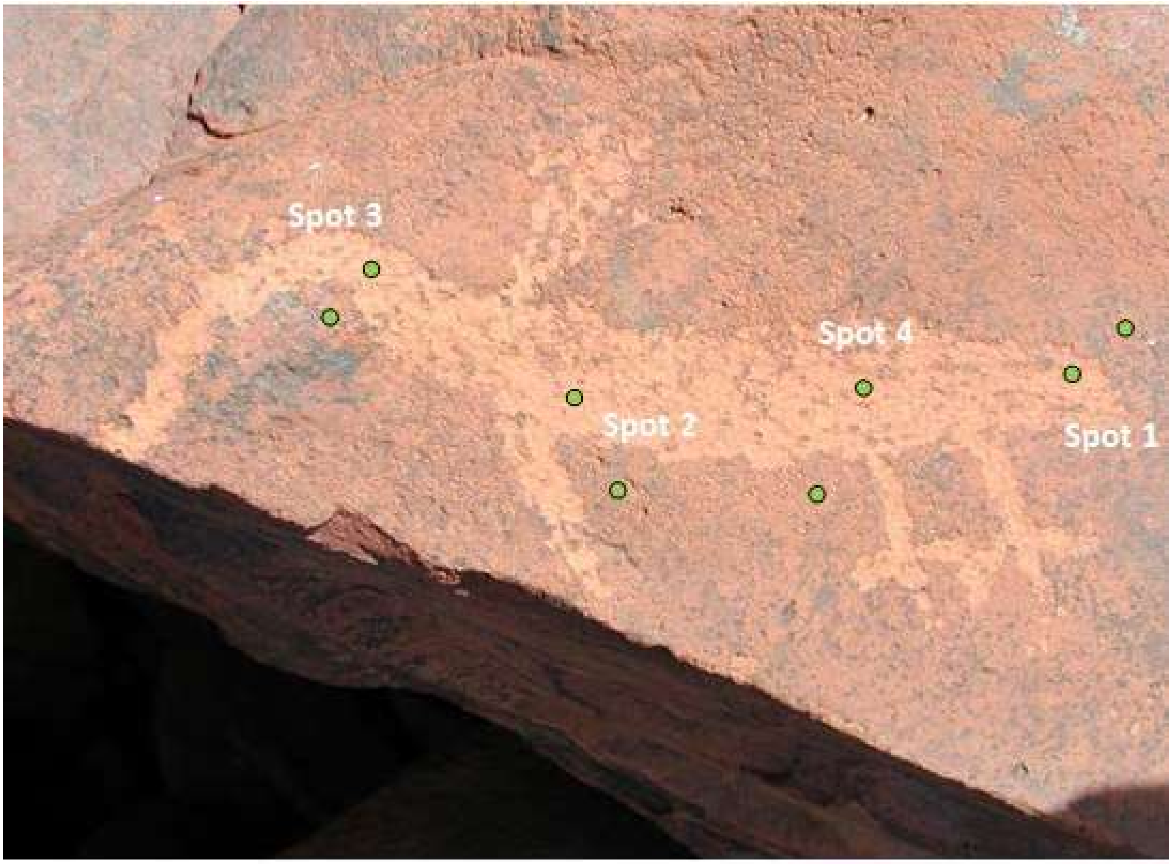


Figure 7: Site 5 – Burrup Road.

Table 9: Average Colour Measurements for Site 5 – Burrup Road (2004 – 2013).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 5 Spot 1 Engraving				
Average 2013	35.93	16.78	19.48	2.83
Average 2012	38.07	17.80	21.02	1.66
Average 2011	38.06	18.67	22.44	0.81
Average 2010	38.74	18.47	22.04	2.52
Average 2009	39.87	19.89	23.79	16.36
Average 2008	31.41	16.39	10.24	1.63
Average 2007	31.64	18.00	10.31	3.99
Average 2006	30.35	14.22	10.23	3.35
Average 2005	30.44	17.57	10.30	2.31
Average 2004	29.72	15.38	10.16	0.00
Site 5 Spot 1 Background				
Average 2013	35.78	15.77	17.56	3.63
Average 2012	35.08	13.69	14.67	0.52
Average 2011	34.58	13.60	14.52	1.10
Average 2010	35.20	14.08	15.30	3.83
Average 2009	31.40	14.32	14.89	4.83
Average 2008	31.59	14.42	10.07	0.95
Average 2007	31.91	13.52	10.00	4.02
Average 2006	32.01	9.51	9.84	6.26
Average 2005	31.55	15.75	10.10	2.89
Average 2004	30.59	13.02	9.99	0.00
Site 5 Spot 2 Engraving				
Average 2013	35.15	18.61	22.35	1.96
Average 2012	37.07	18.97	22.30	2.17
Average 2011	38.17	20.31	23.60	1.09
Average 2010	38.26	19.53	22.85	0.68
Average 2009	37.99	19.53	22.22	14.97
Average 2008	30.46	14.83	10.16	0.92
Average 2007	29.84	14.15	10.17	4.96
Average 2006	31.58	18.80	10.34	1.47
Average 2005	30.55	19.85	10.38	0.11
Average 2004	30.60	19.81	10.29	0.00
Site 5 Spot 2 Background				
Average 2013	31.09	14.44	14.87	0.22
Average 2012	31.16	14.58	15.02	0.24
Average 2011	31.20	14.36	15.11	1.14
Average 2010	32.05	14.77	15.75	0.33
Average 2009	32.16	14.78	15.44	5.42
Average 2008	32.10	14.43	10.03	1.64
Average 2007	31.90	16.06	10.07	1.57
Average 2006	31.51	14.54	10.01	2.70
Average 2005	32.01	17.19	10.14	
Average 2004				

Site 5 Spot 3 Engraving				
Average 2013	38.21	18.94	22.85	1.46
Average 2012	39.26	19.66	23.57	0.35
Average 2011	39.26	19.46	23.86	0.75
Average 2010	40.00	19.48	23.94	2.77
Average 2009	39.13	18.51	21.50	13.37
Average 2008	33.00	22.96	10.48	0.97
Average 2007	33.67	23.66	10.58	2.78
Average 2006	33.32	20.90	10.48	1.55
Average 2005	31.78	21.08	10.40	4.74
Average 2004	33.59	25.45	10.56	0.00
Site 5 Spot 3 Background				
Average 2013	32.53	12.21	13.02	2.61
Average 2012	34.07	13.66	14.55	2.41
Average 2011	34.46	12.52	12.47	5.16
Average 2010	36.45	15.67	16.04	1.50
Average 2009	35.74	14.52	15.39	8.47
Average 2008	30.24	11.06	9.94	7.94
Average 2007	29.30	3.18	9.72	11.04
Average 2006	32.68	13.68	9.94	1.91
Average 2005	31.28	14.98	10.03	0.50
Average 2004	31.10	14.52	10.00	0.00
Site 5 Spot 4 Engraving				
Average 2013	37.69	19.24	22.26	
Site 5 Spot 4 Background				
Average 2013	32.44	14.87	15.68	

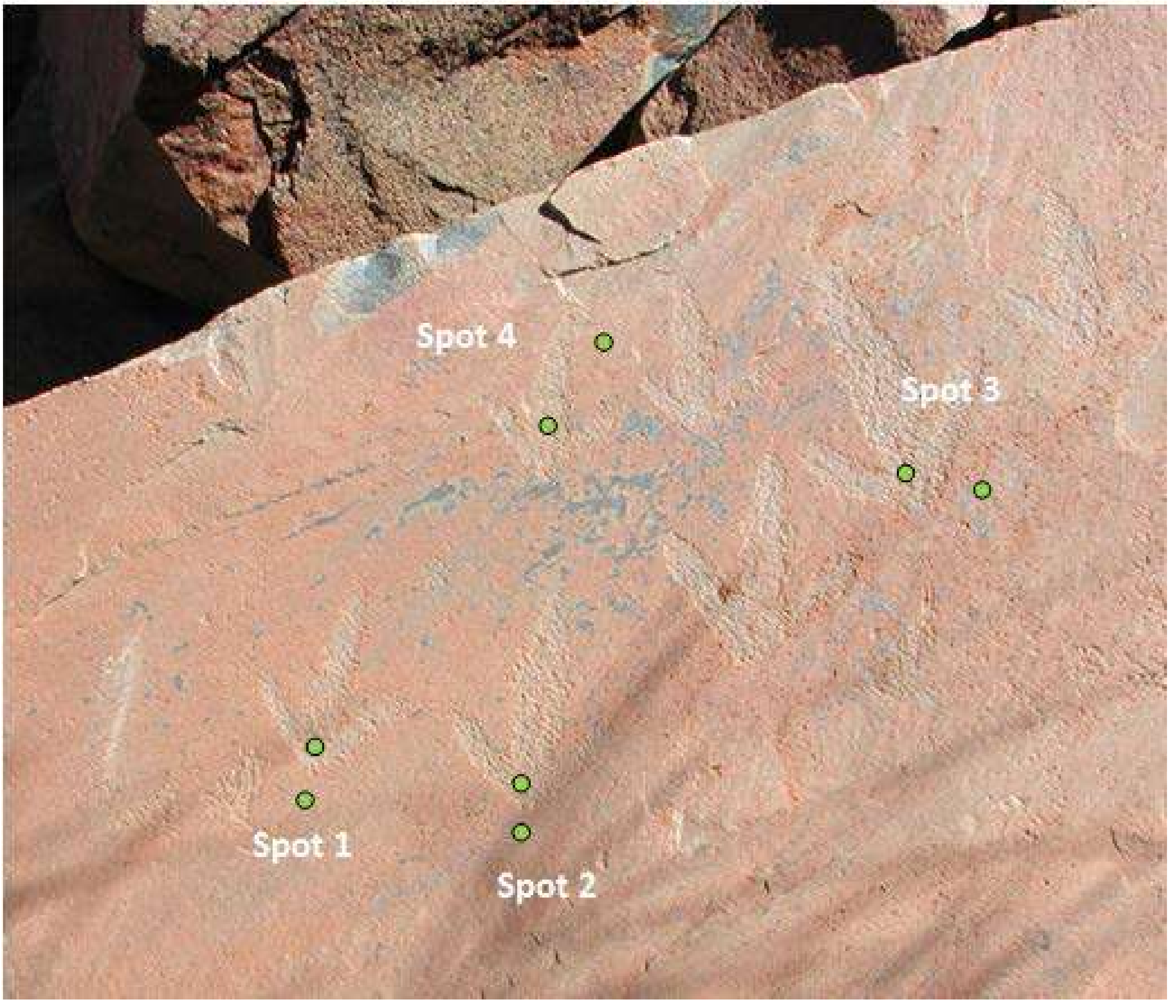


Figure 8: Site 6 – Water Tanks.

Table 10: Average Colour Measurements for Site 6 – Water Tanks (2004 – 2013).

Sample	Colour scale L*	Colour scale a*	Colour scale b*	Colour difference* ΔE (change from previous year)
Site 6 Spot 1 Engraving				
Average 2013	40.92	11.80	17.65	0.97
Average 2012	40.64	11.19	16.96	0.28
Average 2011	40.74	11.34	17.17	0.49
Average 2010	40.31	11.51	17.34	0.72
Average 2009	41.00	11.56	17.13	11.40
Average 2008	33.01	7.50	10.10	0.40
Average 2007	33.05	7.90	10.11	2.37
Average 2006	33.58	10.20	10.14	0.55
Average 2005	33.34	10.70	10.17	1.71
Average 2004	32.16	11.93	10.18	0.00
Site 6 Spot 1 Background				
Average 2013	39.24	12.65	17.11	0.81
Average 2012	39.45	13.27	17.60	0.60
Average 2011	38.87	13.17	17.45	0.73
Average 2010	39.46	13.51	17.72	0.28
Average 2009	39.61	13.34	17.57	9.98
Average 2008	33.39	10.96	10.14	2.82
Average 2007	33.61	13.77	10.19	0.77
Average 2006	33.60	14.54	10.19	1.79
Average 2005	32.98	12.86	10.17	0.95
Average 2004	33.59	13.59	10.18	0.00
Site 6 Spot 2 Engraving				
Average 2013	39.86	11.36	16.85	1.09
Average 2012	38.83	11.70	16.91	1.19
Average 2011	39.97	11.39	16.79	0.40
Average 2010	39.64	11.48	16.99	0.64
Average 2009	40.09	11.47	16.54	10.46
Average 2008	33.00	7.30	10.06	1.42
Average 2007	32.91	8.72	10.10	1.18
Average 2006	32.86	9.89	10.10	0.54
Average 2005	32.38	10.14	10.12	0.67
Average 2004	32.92	9.73	10.10	0.00
Site 6 Spot 2 Background				
Average 2013	38.52	12.80	16.66	1.39
Average 2012	37.91	12.14	15.61	1.93
Average 2011	38.33	13.45	16.96	0.55
Average 2010	38.01	13.23	16.57	1.37
Average 2009	38.49	12.33	15.64	7.53
Average 2008	33.45	11.55	10.10	0.28
Average 2007	33.23	11.37	10.06	0.16
Average 2006	33.38	11.43	10.04	0.26
Average 2005	33.16	11.29	10.06	2.06
Average 2004	33.25	13.34	10.12	0.00

Site 6 Spot 3 Engraving				
Average 2013	38.92	11.68	16.22	0.76
Average 2012	39.31	11.02	16.17	0.74
Average 2011	38.72	11.45	16.03	0.36
Average 2010	38.53	11.62	16.29	11.46
Average 2009 (bird droppings on spot)*	48.77	7.27	13.53	15.84
Average 2008	33.32	7.29	10.04	0.79
Average 2007	33.01	8.02	10.06	0.43
Average 2006	32.87	8.42	10.03	2.11
Average 2005	33.18	10.51	10.12	0.71
Average 2004	33.49	9.87	10.10	0.00
Site 6 Spot 3 Background				
Average 2013	38.48	13.00	16.88	0.33
Average 2012	38.55	13.33	16.93	1.48
Average 2011	38.91	12.00	16.39	0.63
Average 2010	38.65	12.30	15.90	1.20
Average 2009	38.57	13.30	16.55	8.29
Average 2008	33.52	11.97	10.12	2.39
Average 2007	33.31	14.35	10.18	4.31
Average 2006	33.41	10.04	10.02	3.87
Average 2005	33.32	13.90	10.16	1.13
Average 2004	33.59	12.80	10.14	0.00
Site 6 Spot 4 Engraving				
Average 2013	41.12	10.97	16.58	
Site 6 Spot 4 Background				
Average 2013	39.43	13.37	17.05	

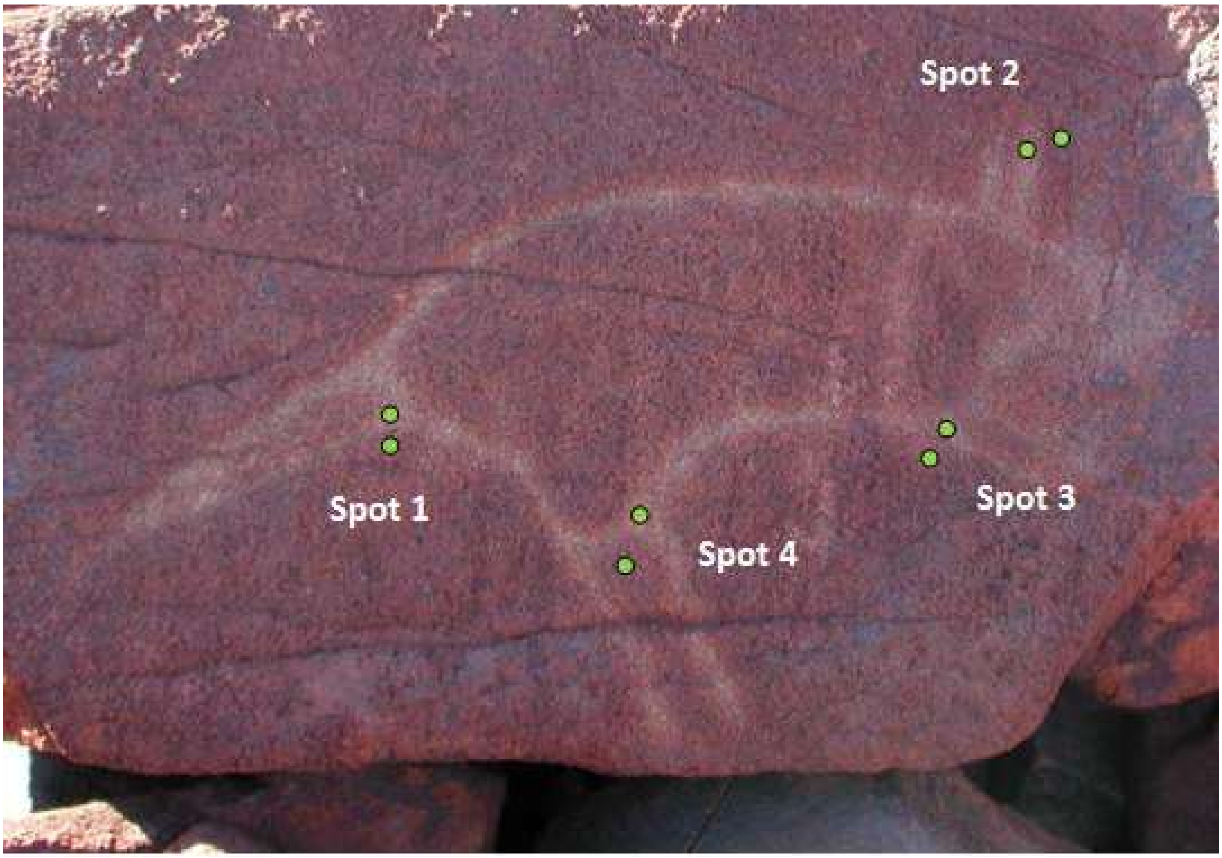


Figure 9: Site 7 – Deep Gorge.

Table 11: Average Colour Measurements for Site 7 – Deep Gorge (2004 – 2013).

Sample	Colour scale L*	Colour scale a*	Colour scale b*	Colour difference* ΔE (change from previous year)
Site 7 Spot 1 Engraving				
Average 2013	34.24	13.87	17.79	0.95
Average 2012	35.06	14.19	18.15	2.77
Average 2011	37.71	14.56	18.85	1.40
Average 2010	39.05	14.76	19.20	2.54
Average 2009	36.54	14.77	18.82	10.51
Average 2008	31.33	11.79	10.19	7.05
Average 2007	29.19	5.08	9.84	0.79
Average 2006	28.43	5.29	9.82	11.03
Average 2005	31.71	15.80	10.21	11.33
Average 2004	27.18	5.43	9.70	0.00
Site 7 Spot 1 Background				
Average 2013	29.54	13.15	14.93	0.75
Average 2012	29.18	13.81	14.96	1.42
Average 2011	27.90	13.79	14.34	1.04
Average 2010	28.73	14.07	14.89	1.14
Average 2009	29.81	13.97	15.25	8.35
Average 2008	29.14	7.58	9.91	2.20
Average 2007	29.24	9.78	9.94	1.83
Average 2006	29.93	11.48	9.94	1.82
Average 2005	29.32	13.19	9.93	0.48
Average 2004	29.33	13.66	10.00	0.00
Site 7 Spot 2 Engraving				
Average 2013	32.87	14.21	16.49	1.73
Average 2012	33.76	12.98	15.66	2.57
Average 2011	33.90	15.17	17.00	0.29
Average 2010	33.84	14.90	17.10	0.94
Average 2009	34.65	15.29	17.38	12.25
Average 2008	28.22	8.11	9.82	0.64
Average 2007	28.39	8.72	9.86	8.48
Average 2006	26.83	0.39	9.52	5.20
Average 2005	28.02	5.45	9.67	4.05
Average 2004	26.41	1.75	9.45	0.00
Site 7 Spot 2 Background				
Average 2013	27.39	12.91	13.16	4.30
Average 2012	31.50	13.70	14.17	2.90
Average 2011	28.99	14.85	15.06	1.80
Average 2010	30.76	14.52	14.98	1.96
Average 2009	30.27	16.07	16.09	9.95
Average 2008	29.92	8.30	9.88	3.36
Average 2007	29.23	11.58	9.91	0.42
Average 2006	29.50	11.26	9.91	1.95
Average 2005	28.79	13.08	9.88	2.70
Average 2004	30.96	11.48	9.90	0.00

Site 7 Spot 3 Engraving				
Average 2013	34.09	14.02	16.40	1.02
Average 2012	34.29	13.18	15.84	1.72
Average 2011	35.02	14.46	16.72	0.84
Average 2010	35.67	13.94	16.56	2.13
Average 2009	33.55	13.80	16.35	22.39
Average 2008	26.30	-6.19	9.35	0.46
Average 2007	26.21	-5.73	9.33	12.77
Average 2006	28.40	6.84	9.80	12.35
Average 2005	26.08	-5.28	9.29	
Average 2004	No measurements			
Site 7 Spot 3 Background				
Average 2013	30.87	14.55	16.01	2.03
Average 2012	29.65	13.66	14.65	3.37
Average 2011	26.88	12.44	13.19	0.89
Average 2010	27.76	12.45	13.09	1.88
Average 2009	26.11	11.90	12.37	8.69
Average 2008	28.40	3.95	9.73	1.29
Average 2007	27.72	2.85	9.65	8.41
Average 2006	29.79	11.00	9.91	3.17
Average 2005	28.08	8.33	9.75	5.63
Average 2004	29.62	13.73	9.98	0.00
Site 7 Spot 4 Engraving				
Average 2013	38.03	15.29	19.25	
Site 7 Spot 4 Background				
Average 2013	30.26	12.88	13.97	

Figure 10: Site 8 – King Bay South.

Table 12: Average Colour Measurements for Site 8 – King Bay South (2004 – 2013).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 8 Spot 1 Engraving				
Average 2013	35.76	14.25	15.70	1.41
Average 2012	34.52	14.22	16.37	1.92
Average 2011	34.93	13.37	14.69	3.22
Average 2010	36.47	15.05	16.96	4.45
Average 2009	36.47	16.58	21.14	13.76
Average 2008	31.37	10.33	9.99	2.21
Average 2007	31.91	12.48	9.97	1.49
Average 2006	31.74	13.95	10.07	0.74
Average 2005	31.20	14.45	10.07	2.16
Average 2004	32.38	16.26	10.06	0.00
Site 8 Spot 1 Background				
Average 2013	32.75	11.93	12.31	0.73
Average 2012	32.26	11.79	12.84	0.95
Average 2011	32.82	11.97	12.09	0.20
Average 2010	32.78	11.99	12.29	5.66
Average 2009	32.57	15.21	16.94	8.43
Average 2008	32.10	10.68	9.85	0.24
Average 2007	31.92	10.52	9.83	1.70
Average 2006	31.35	8.92	9.84	3.52
Average 2005	31.49	12.44	9.91	1.14
Average 2004	31.55	11.30	9.85	0.00
Site 8 Spot 2 Engraved				
Average 2013	36.38	14.88	15.98	1.04
Average 2012	35.57	14.32	15.64	0.62
Average 2011	35.87	14.32	15.10	1.20
Average 2010	34.79	13.88	14.82	0.71
Average 2009	35.43	13.82	14.52	8.06
Average 2008	30.37	9.54	9.94	3.17
Average 2007	30.98	12.65	9.98	5.30
Average 2006	29.48	7.57	9.86	6.39
Average 2005	31.53	13.62	9.98	1.78
Average 2004	30.16	12.48	9.96	0.00
Site 8 Spot 2 Background				
Average 2013	32.42	11.72	12.05	0.57
Average 2012	32.54	11.19	11.87	0.87
Average 2011	32.17	11.93	12.17	0.31
Average 2010	32.33	12.02	12.42	0.80
Average 2009	33.08	11.91	12.16	4.02
Average 2008	31.51	9.02	9.85	1.01
Average 2007	31.34	10.01	9.84	1.57
Average 2006	31.21	8.44	9.82	2.24
Average 2005	30.75	10.63	9.86	0.55
Average 2004	31.22	10.92	9.84	0.00

Site 8 Spot 3 Engraved				
Average 2013	33.35	15.46	19.45	0.55
Average 2012	32.85	15.23	19.44	2.13
Average 2011	34.80	16.06	19.64	2.23
Average 2010	32.95	15.46	18.54	4.19
Average 2009	34.73	13.81	15.14	7.22
Average 2008	30.24	11.20	10.11	0.25
Average 2007	30.11	11.41	10.10	0.98
Average 2006	30.57	12.27	10.14	1.37
Average 2005	29.27	11.86	10.06	2.31
Average 2004	30.33	13.91	10.14	0.00
Site 8 Spot 3 Background				
Average 2013	30.73	13.52	14.69	0.98
Average 2012	31.32	13.62	15.47	2.75
Average 2011	32.51	15.12	17.45	0.62
Average 2010	32.11	14.65	17.36	5.78
Average 2009	33.28	12.07	12.32	3.20
Average 2008	31.41	13.35	10.06	2.24
Average 2007	30.47	11.32	9.94	1.07
Average 2006	30.51	12.39	10.01	1.20
Average 2005	30.83	13.55	10.02	0.66
Average 2004	31.46	13.36	9.95	0.00
Site 8 Spot 4 Engraved				
Average 2013	34.11	15.20	17.67	
Site 8 Spot 4 Background				
Average 2013	30.68	12.94	14.32	

The averaged colour change for each site is presented in

Table 13, which is an overall average for each of the six spots measured on a petroglyph[3]. The colour change for both the Southern and Northern sites for the period are reasonably consistent over the measurement period, with the exception of the 2008-09 values. The period coincides with transition between corrected BYK data and collected KM data (i.e. 2008 - converted BYK data, 2009 - collected KM data. The conversion model was constructed on cleaned (i.e. outliers removed) 2011/12 data and, as such, was tailored to fit this data extremely well. However, this tailoring may have resulted in the model fitting other years' data less well, thus introducing an element of error when comparing converted data with collected data. At any given time interval, including 2008-09, the average change at the Southern and Northern sites are comparable, indicating that accelerated weathering at Southern sites within close proximity to industrial complexes was not observed.

[3] Spot 4 has not been included as initial measurements were taken in 2013, therefore no colour change for previous year could be calculated.

Table 13: Averaged colour change for each site

Site	Averaged site-specific colour change								
	ΔE 12-13	**ΔE 11-12**	**ΔE 10-11**	**ΔE 09-10**	**ΔE 08-09**	**ΔE 07-08**	**ΔE 06-07**	**ΔE 05-06**	**ΔE 04-05**
4	**0.79**	1.50	1.79	2.70	8.54	1.15	1.15	1.94	1.04
5	**2.12**	1.23	1.68	1.94	10.57	2.34	4.73	2.31	2.11
6	**0.89**	1.04	0.53	2.61	10.58	1.35	1.54	1.38	1.21
7	**1.80**	2.46	1.08	1.69	12.02	2.50	5.45	5.70	4.84
8	**0.88**	1.54	1.30	3.60	7.45	1.52	2.02	2.18	1.44
Overall southern sites average	**1.30**	1.55	1.27	2.51	9.83	1.77	2.98	2.70	2.13
1	**2.15**	1.60	1.37	1.16	8.65	2.47	2.83	2.46	1.43
2	**1.03**	1.59	1.31	2.30	9.63	2.10	1.79	2.33	1.49
Overall northern sites average	**1.59**	1.59	1.34	1.73	9.14	2.28	2.31	2.39	1.46

The ten consecutive years of colour change measurements have allowed an examination of whether any trends are apparent at the sites, either individually or as a group, and whether the colour change measurements at the southern test sites are consistently or significantly different to those at the northern control sites.

Considering the year to year ΔE values for 2004–13, which indicates the colour change over the ten year interval from 2004 to 2013, site 7 consistently displayed the greatest year to year colour change up to 2009. For sites 4, 6 and 8 (southern), the colour change values for the interval 2004–13 were comparable to or lower than northern sites 1 and 2. With the northern sites as the control sites, and the southern sites as test sites, there were no indications that changes at both sites were substantively different.

Where the colour difference appeared to have larger values overall (sites 5 and 7), this is believed to be partially due to the surface roughness of the rock, which influenced the placement of the spectrophotometer. This is supported by the improvement in the consistency of the results at these sites from 2009 onwards, where the new Konica Minolta spectrophotometer, with an improved head configuration, was deployed for data collection. At site 5, spot 3 there is a large patch of black patina (see Figure 7) which means that colour measurement is much more dependent on instrument placement at that spot. The site with the smoothest rock face (site 6, Figure 8), however, did not consistently record the lowest colour change values so measurement repeatability is therefore dependent on more than just surface roughness.

3.3.2 BACKGROUND – ENGRAVING COLOUR DIFFERENCE

The colour difference between the background and petroglyph for each spot is presented in

Table 14 and plotted in Figure 11 – 16.

The two data absences in the table in 2004 are because no data was collected for site 5 spot 2 background and site 7 spot 3 engraving during the initial year of collection. The colour difference between the background and petroglyph is an indication of the colour contrast, and to some extent, the “readability” of the petroglyph. The readability is also provided by the depth of the image engraving and texture of the image lines. Colour difference between the petroglyph and engraving was generally lowest at Site 6 corresponding with visual observations.

The unusually large colour difference observation for site 5, spot 3 in 2007 (also observed in the L*a*b* measurements) is believed to be due to spectrophotometer placement as discussed previously. The sample location in that region has a large patch of black patina which means colour measurement is much more dependent on the instrument location at that spot. The patch of black patina could also account for the greater overall year to year variance observed at spot 3, compared to spot 1 and 2 for the same petroglyph.

In the colour change report from 2010 (Lau et al., 2010) it was indicated the data would be represented against a line of best fit to indicate the overall trend. This is presented here for each individual engraving-background spot-pair, for each site (Figure 11-16).

Over time, a consistent trend toward smaller colour differences between background and petroglyph would indicate either background fading or darkening of the petroglyph, or both. Site 6 exhibits the least colour contrast between the petroglyph and background, with lower colour difference values; however Figure 15 shows that this difference has been stable over time, with the exception of the anomalous point for Spot 3, 2009, which was attributable to bird droppings on the petroglyph making accurate colour readings difficult. For Site 1 at the Northern sites, there is an observable slight trend toward higher average colour difference. For Site 2, there is a more evident trend towards increased averaged colour difference; however this could be a function of the data conversion as all spots exhibit a sharp increase at 2009. For the southern sites, the measurements at Site seven are variable; consistent with the roughness of the surface, but a linear fit indicates a decreasing colour difference trend for spots 2 and 3, and an increasing trend for spot 1. Sites 4, 5, and 8 all exhibit a slight increasing trend. As shown in the plots presented in Figure 11-16, the slight trend towards increasing contrast between the background and engraved image in the southern test sites was not observed to be markedly different from that observed in the northern control sites data.

Table 14: Colour difference between background and petroglyph

Spot 1	Site 1	Site 2	Site 4	Site 5	Site 6	Site 7	Site 8
Average 2013	**12.4**	**10.0**	**7.1**	**2.2**	**2.0**	**5.5**	**5.1**
Average 2012	12.3	10.9	5.8	8.1	2.5	6.7	4.8
Average 2011	12.2	13.1	6.5	10.0	2.6	10.8	3.6
Average 2010	11.3	12.0	6.1	8.8	2.2	11.2	6.7
Average 2009	10.5	9.0	7.0	13.5	2.3	7.7	5.9
Average 2008	11.7	4.3	3.7	2.0	3.5	4.8	0.8
Average 2007	9.0	1.5	4.8	4.5	5.9	4.7	2.0
Average 2006	11.6	2.9	3.5	5.0	4.3	6.4	5.1
Average 2005	9.4	1.8	3.2	2.1	2.2	3.6	2.0
Average 2004	6.4	2.0	3.2	2.5	2.2	8.5	5.0
Spot 2							
Average 2013	**10.7**	**18.7**	**3.4**	**9.5**	**2.0**	**6.5**	**6.4**
Average 2012	7.2	17.5	2.9	10.4	1.7	2.8	5.8
Average 2011	11.8	18.5	4.1	12.5	2.6	5.3	5.3
Average 2010	7.6	18.4	1.9	10.6	2.4	3.8	3.9
Average 2009	10.7	18.3	3.9	10.1	2.0	4.6	3.8
Average 2008	3.8	4.2	2.7	1.7	4.3	1.7	1.3
Average 2007	5.1	2.3	3.8	2.8	2.7	3.0	2.7
Average 2006	5.6	4.4	6.5	4.3	1.6	11.2	1.9
Average 2005	2.9	3.9	4.0	3.0	1.4	7.7	3.1
Average 2004	4.3	1.6	5.9		3.6	10.8	1.9
Spot 3							
Average 2013	**11.4**	**9.8**	**6.7**	**13.2**	**1.5**	**3.3**	**5.8**
Average 2012	12.2	12.0	7.4	12.0	2.5	4.8	4.5
Average 2011	12.4	12.5	12.3	14.2	0.7	9.1	3.3
Average 2010	12.9	8.9	5.1	9.5	0.8	8.8	1.7
Average 2009	13.7	13.0	6.4	8.1	12.2	8.7	3.6
Average 2008	7.5	3.7	0.4	12.2	4.7	10.4	2.4
Average 2007	2.7	4.6	3.9	21.0	6.3	8.7	0.4
Average 2006	6.3	3.9	1.5	7.3	1.7	4.4	0.2
Average 2005	6.8	4.4	1.2	6.1	3.4	13.8	2.3
Average 2004	7.9	3.5	1.1	11.2	2.9		1.3

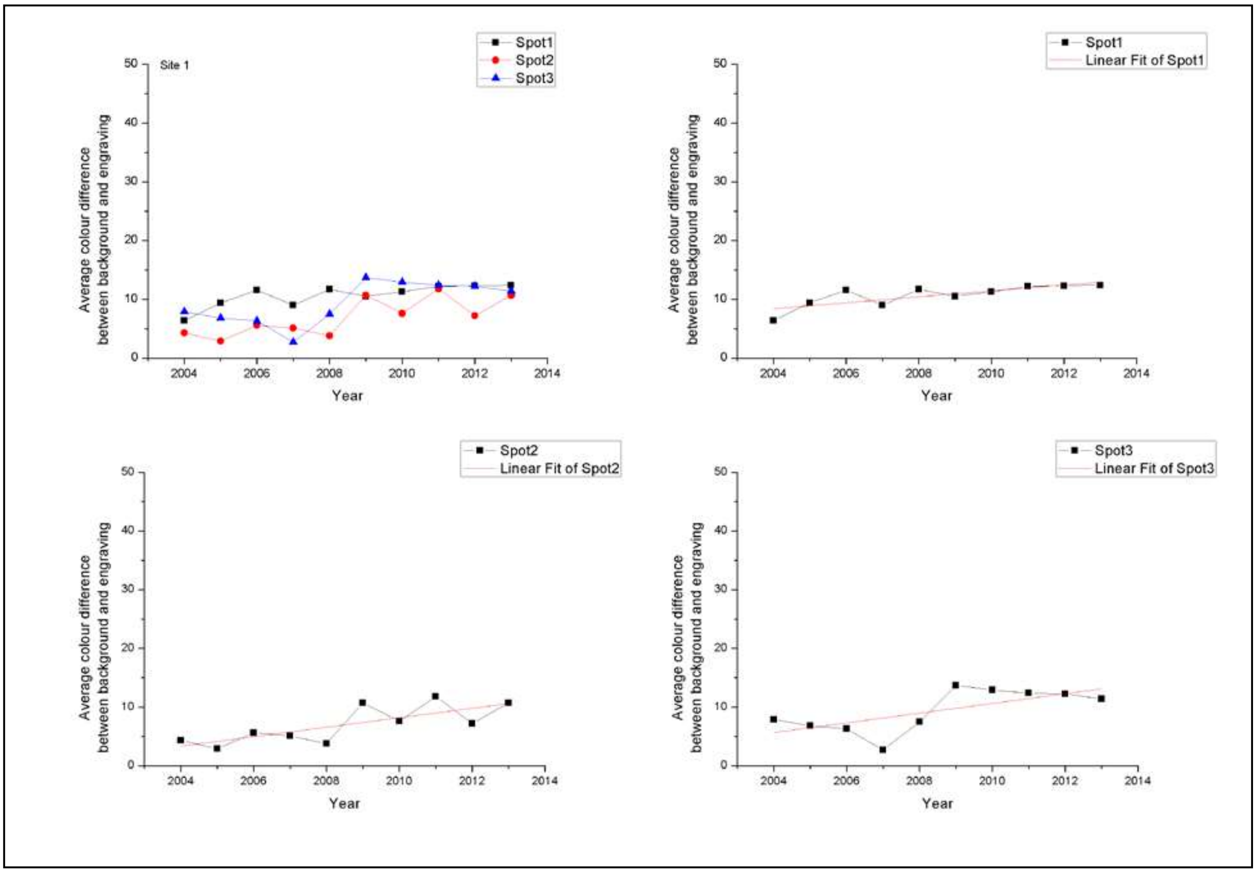


Figure 11: Colour differences between engraving and background for each spot examined at Site 1 – Dolphin Island.

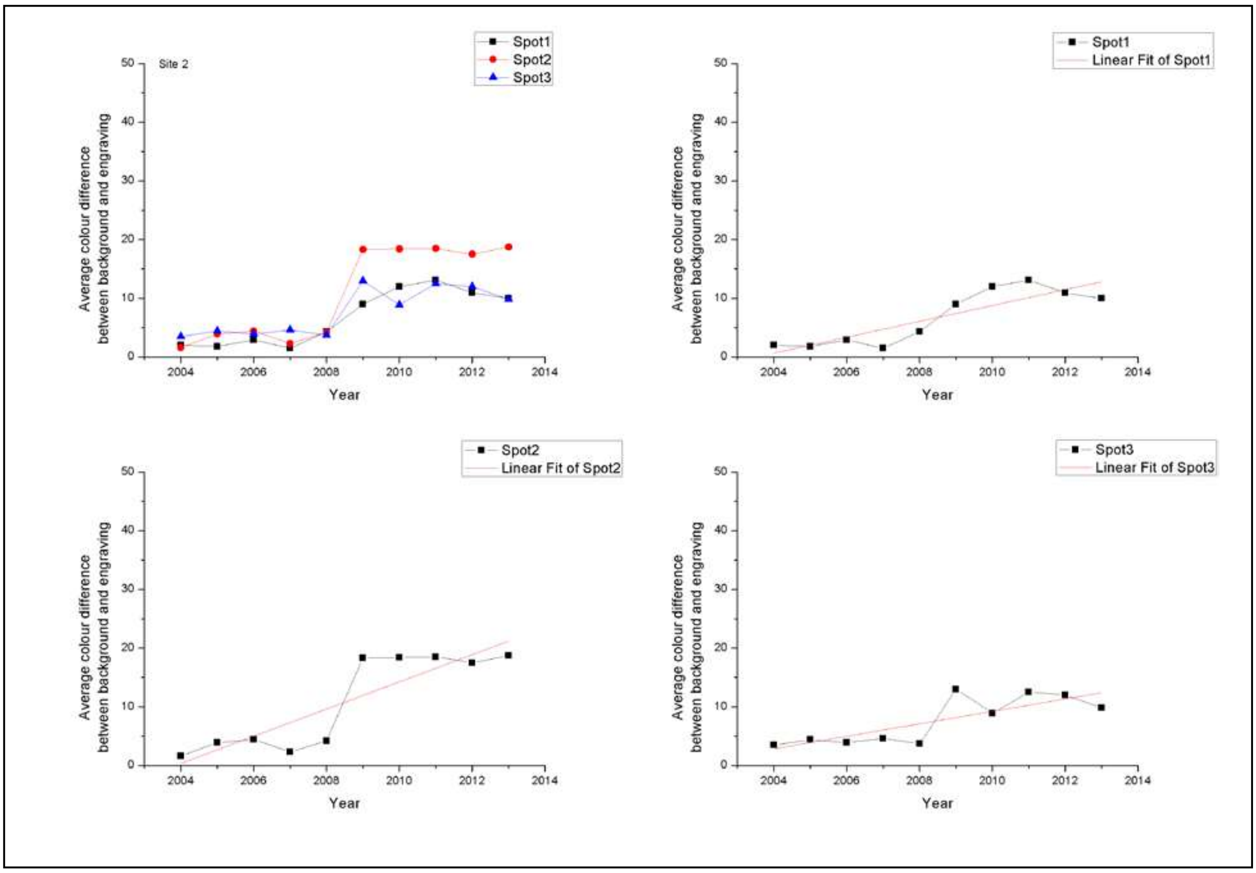


Figure 12: Colour differences between engraving and background for each spot examined at Site 2 – Gidley Island.

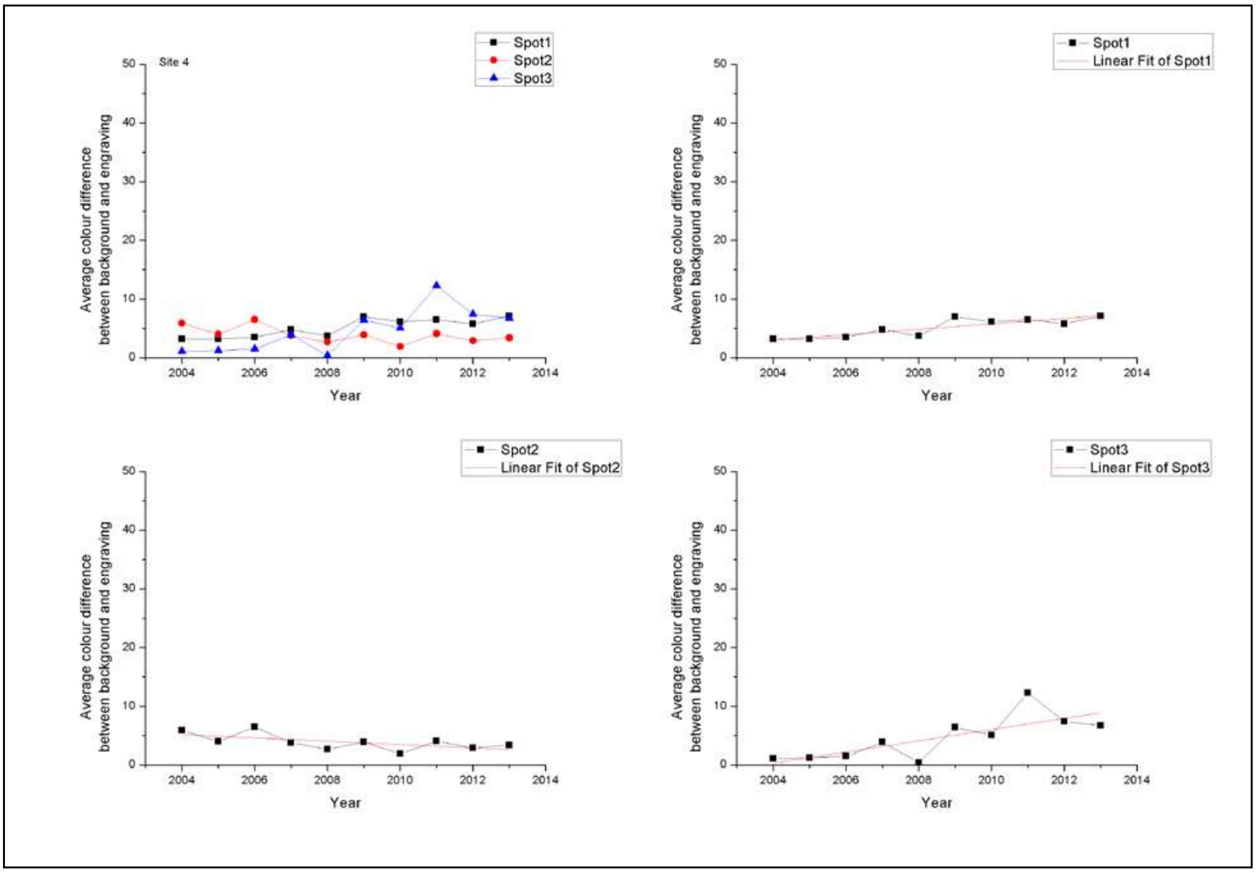


Figure 13: Colour differences between engraving and background for each spot examined at Site 4 – Woodside.

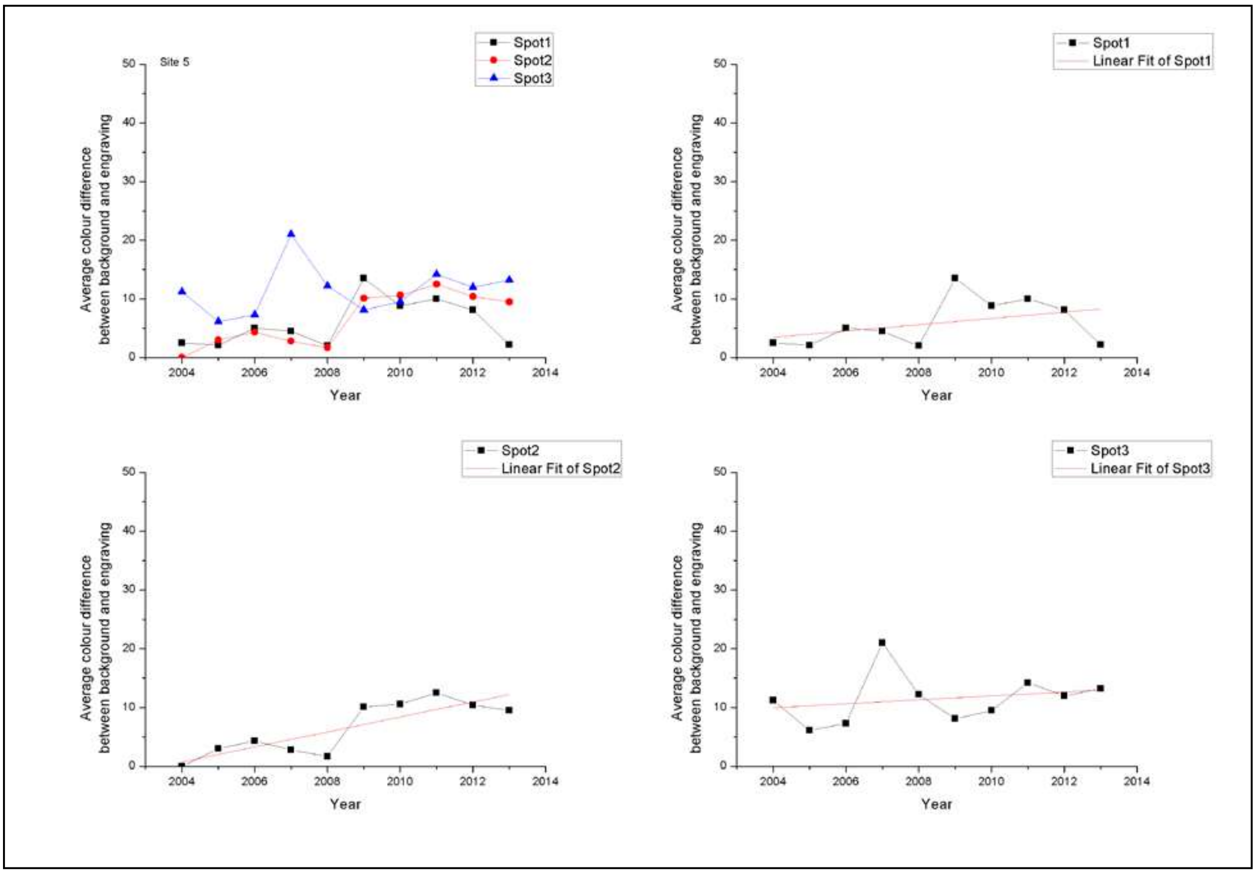


Figure 14: Colour differences between engraving and background for each spot examined at Site 5 – Burrup Road. Site 5 spot 3 is believed to exhibit high variance in single years due to irregular measurements.

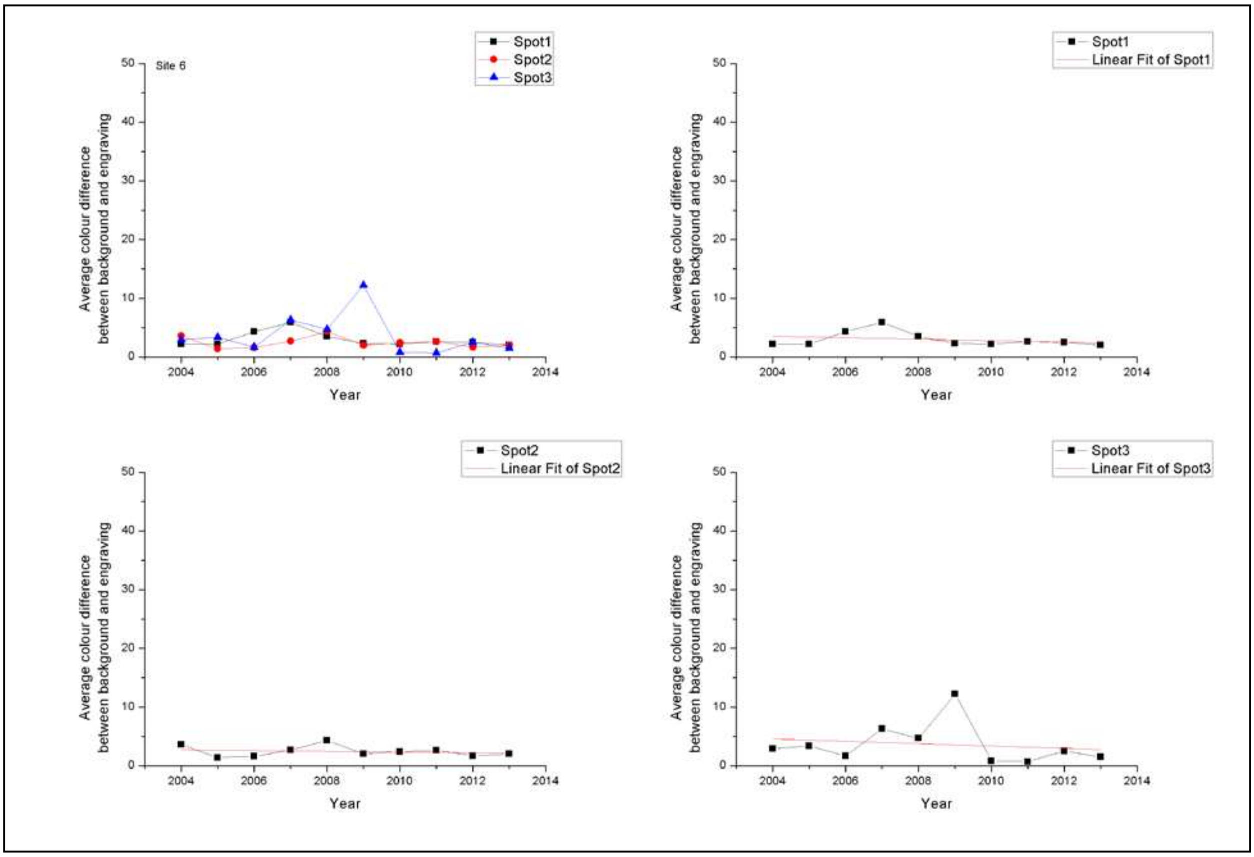


Figure 15: Colour differences between engraving and background for each spot examined at Site 6 – Water Tanks.

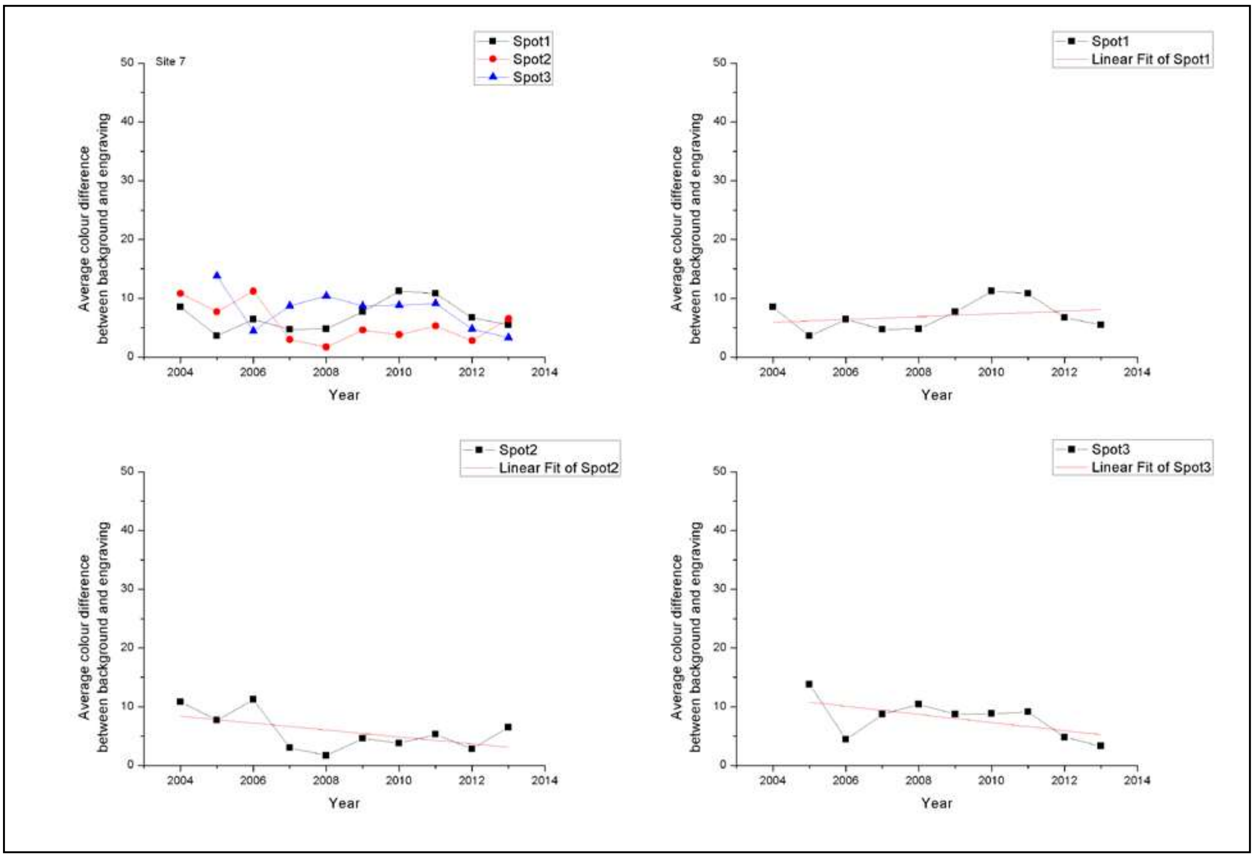


Figure 16: Colour differences between engraving and background for each spot examined at Site 7 – Deep Gorge. Site 7 spot 2 is believed to exhibit high variance in single years due to irregular measurements.

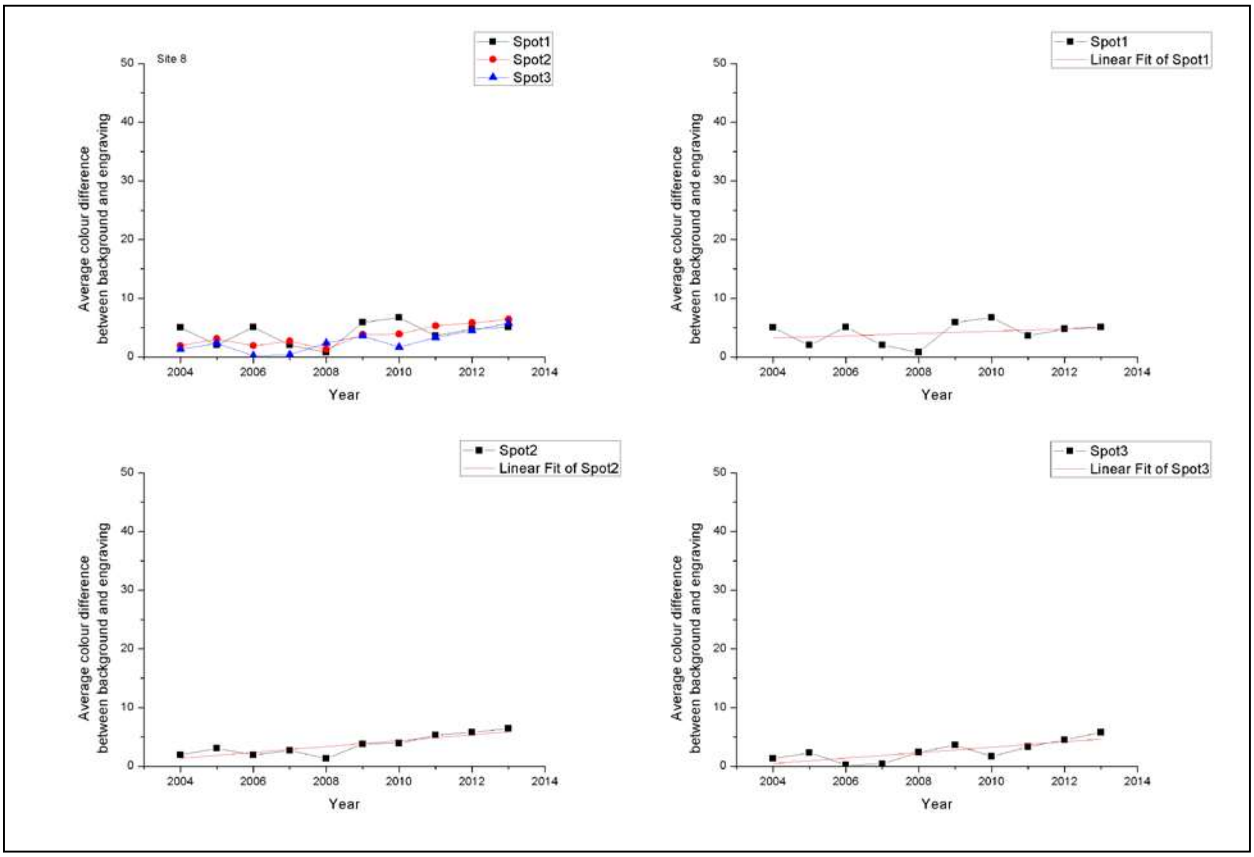


Figure 17: Colour differences between engraving and background for each spot examined at Site 8 – King Bay South.

3.3.3 ANOVA ANALYSIS OF 2013 COLOUR MEASUREMENTS

During the data collection field trip in 2013, background and engraving colour measurements were collected at 4 spots on each petroglyph. Colour measurements, in L*a*b* format, were collected from 2 Northern (control) sites and 5 Southern (test) sites. The Northern and Southern sites are compared below for each of these variables separately.

L*

The variation in lightness across the sites is indicated in Figure 18. The sites are clearly different from each other. The Northern sites 1 and 2 encompass a wider variation than the other sites.

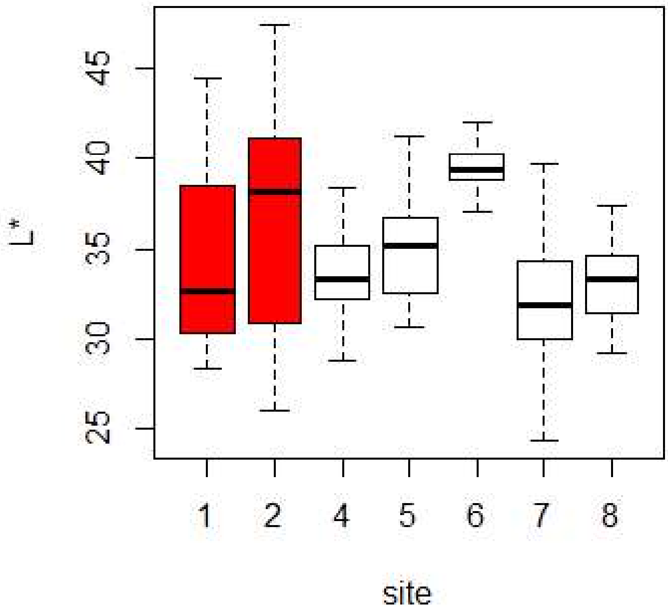


Figure 18: Boxplots of lightness L* at each site. Northern sites are coloured red in the plots.

Figure 19 shows the contrast in lightness between background and engraving is greater at the Northern sites, indicating a higher 'readability' of the petroglyph. The background is slightly lighter on average at Southern sites, but the engravings are considerably lighter at Northern sites.

Linear mixed effect models were fitted for L*, a* and b*, comparing Northern and Southern sites on background and engraving across the various spots at each site (taken as a random sample of all spots on each site and sites in each location). The North/South difference is statistically significant for L*, with a p value of 0.019.

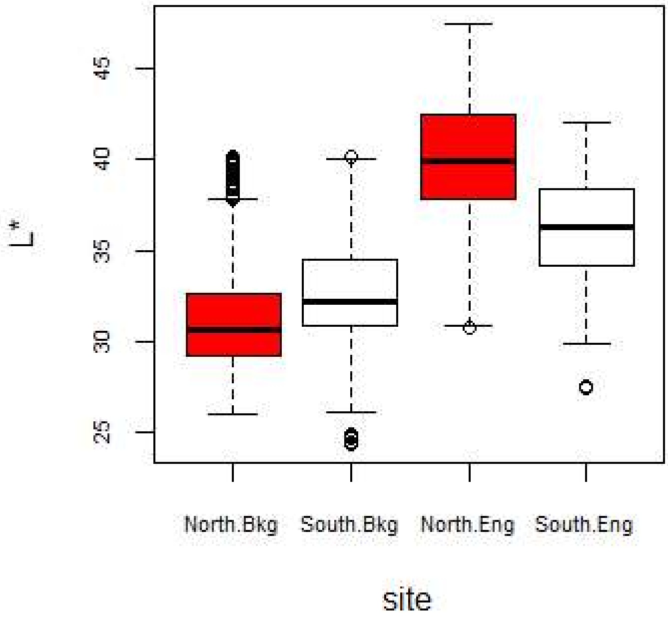


Figure 19: Boxplots showing how lightness varies between Northern and Southern sites on background and engraving. Northern sites are coloured red in the plots. Bkg stands for background; Eng for engraving.

a*

The green-red contrast across the sites is indicated in Figure 20. The sites are again clearly different from each other. The Northern sites are noticeably less red than most of the other sites. (The effect would be even more pronounced but for the fourth spot at site 2, which is the lightest of all spots on any site. This explains the long tail in the boxplot for site 2 in Figure 20.)

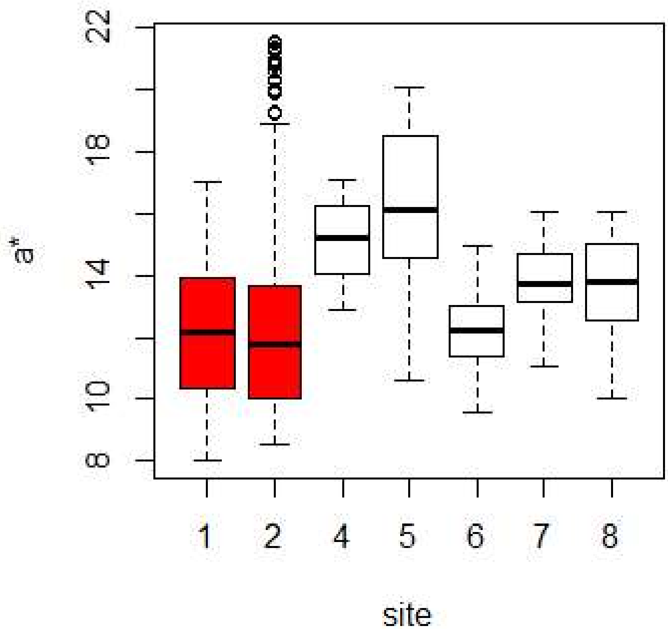


Figure 20: Boxplots of the green-red contrast a* at each site. Northern sites are coloured red in the plots (though their a* values indicate they are less red than most of the other sites).

Figure 21 shows the green-red contrast is generally similar on background and engraving, though the difference is slightly greater at Southern sites. The fourth spot on site 2, however, is the most red in its background of any spot on any site (represented in Figure 21 as a group of outliers above the North.Bkg boxplot), while the engraving is far less red. The variation between sites is thus far greater in the North of the peninsula.

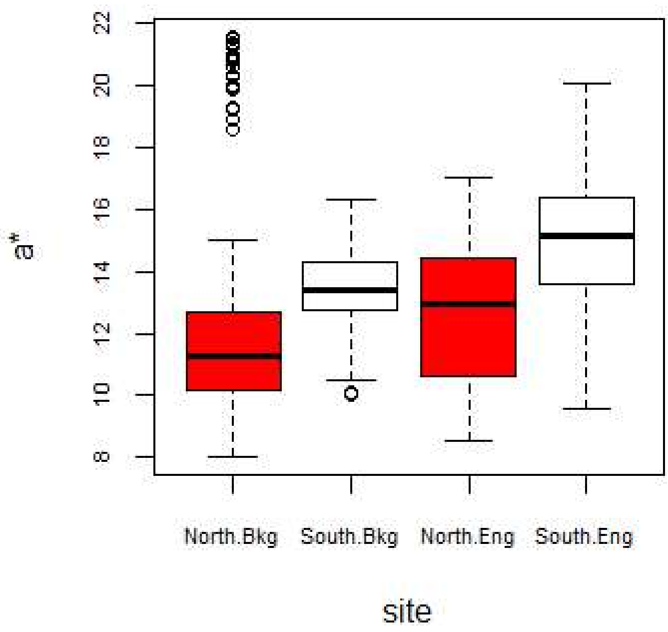


Figure 21: Boxplots showing how the green-red contrast varies between Northern and Southern sites on background and engraving. Northern sites are coloured red in the plots. Bkg stands for background; Eng for engraving.

The linear mixed effect model shows the North/South difference is significant for a*, with a p value of 0.00008.

b*

The blue-yellow contrast across the sites is indicated in Figure 22. The sites are again clearly different from each other. The Northern sites, particularly Site 1, are slightly less yellow on average than the other sites.

The blue-yellow contrast is almost identical on the engravings in both the North and South of the peninsula, but the backgrounds in Northern sites are less yellow than those in the South (Figure 23). The fourth spot on site 2, however, is the most yellow in its background of any spot on any site (thus the North.Bkg boxplot in Figure 23 has a long tail). The variation between sites is thus again far greater in the North of the peninsula.

0.029.

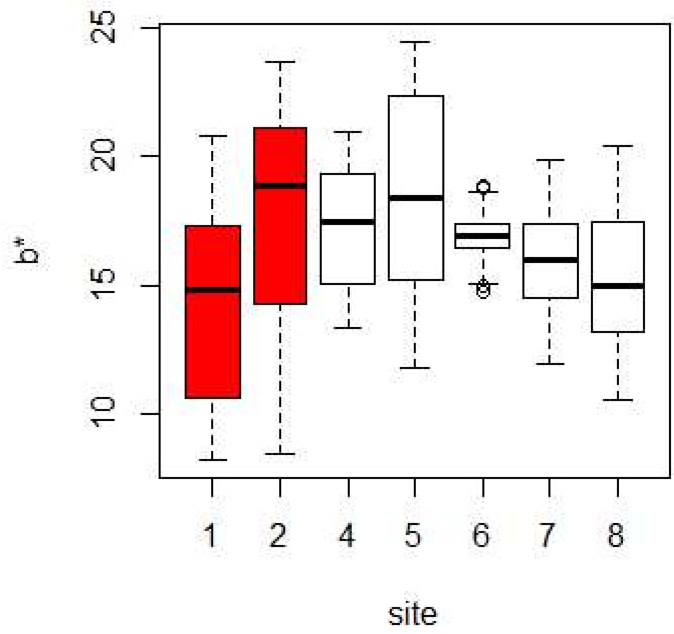


Figure 22:Boxplots of the blue-yellow contrast b* at each site. Northern sites are coloured red in the plots. Site 1 in particular is less yellow than the other sites.

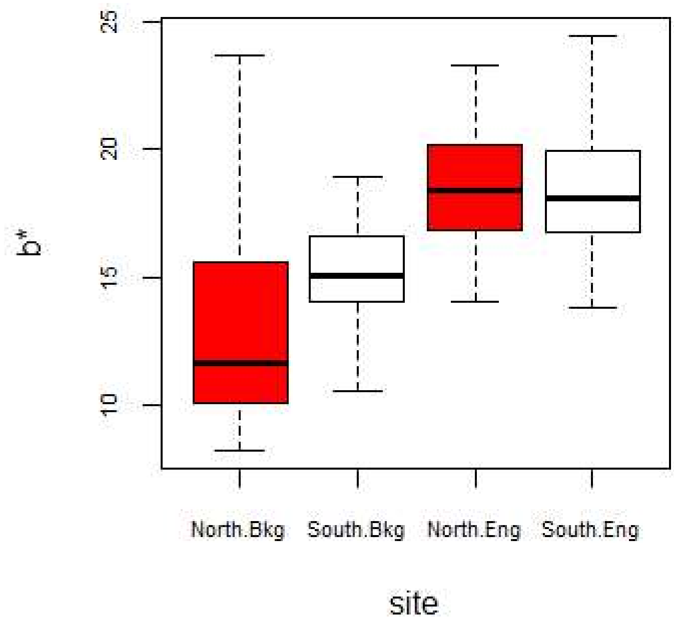


Figure 23: Boxplots showing how the blue-yellow contrast varies between Northern and Southern sites on background and engraving. Northern sites are coloured red in the plots. Bkg stands for background; Eng for engraving.

The linear mixed effect model shows the North/South difference is significant for b*, with a p value of 0.029.

The Northern sites are found to be slightly lighter (in the engravings only, not in the backgrounds), less red and less yellow (in the backgrounds only) than the Southern sites. The differences are statistically significant.

4. Comparison between 2 spectrophotometers for colour measurement

The initial measurements (2004 to 2009) were acquired using only the BYK colour meter. In 2009 some of the automated memory retention functions of the BYK spectrophotometer started to become less reliable, requiring laborious manual data saving. Calibration and instrument performance were unaffected. It was decided to pair the BYK instrument with a more modern Konica Minolta spectrophotometer and perform measurements using both instruments to explore the possibility of substituting instruments. Since 2009, each site has been measured in duplicate using the two instruments. This section reports on the correlation between L*, a* and b* colour measurements obtained between the 2 instruments and the possibility of replacing the BYK by the KM spectrophotometer altogether for field measurements. Analyses in this report suggest that background and engraving KM measurements can be predicted with statistical accuracy from those BYK at the sites and spots for which data is available.

Analysis of variance for regression of KM data on BYK data for each of L*, a* and b* is given in Tables 14-16. (Regression analysis is more meaningful on the three component measurements of colour rather than on the combined ΔE statistic. This also removes the dependence of ΔE on the initial colour.) It would be useful in general to be able to predict KM measurements from BYK; however, for the purposes of this calibration, only predictions of background and engraving colour at the chosen sites and spots are required.

Since the data were collected in a structured way, it is possible to predict KM measurements with reasonable accuracy simply from the site, spot and type (engraving or background) of the measurement. Including this data improves prediction markedly. However, and reassuringly, within each site, spot and engraving type the BYK measurement is an effective predictor of KM measurement, particularly for L* and a*.

Observations: L*

Table 14 shows lightness to vary significantly across the sites and the spots at each site. Also the engravings tend to be lighter than the background, to varying extents at each site and each spot. Allowing for these effects, however, the BYK measurement of L* is a very strongly significant predictor of the KM measurement of L*. (There is also some evidence that the relationship of measurements from the two machines differs at different spots.)

Table 15: Analysis of variance table for predicting KM measurements of L* from BYK measurements of L*.

Source of variation	df	SS	MS	F	p
site	6	710.3	118.4	91.9	0.00001
spot	14	132.2	9.4	6.2	0.0008
engraving	1	923.7	923.7	4842.7	0.009

engraving × site	6	321.3	53.5	79.0	0.00002
engraving × spot	14	104.4	7.5	5.2	0.002
L	1	65.9	65.9	83.0	0.00000000002
L × site	6	7.7	1.3	1.6	0.166
L × spot	14	21.5	1.5	1.9	0.051
L × engraving	1	0.2	0.2	0.2	0.627
L × engraving × site	6	4.1	0.7	0.9	0.537
L × engraving × spot	14	20.1	1.4	1.8	0.071
error	41	32.6	0.8		

Figure 24 shows that the KM measurements can be modelled fairly accurately using BYK measurements and site, spot and engraving information (and interactions among the latter variables). The value of R^2 is 0.96, indicating 96 % of the variation in L* observations is explained by the model. (This is the square of the correlation coefficient for the data in Figure 1.) The residual standard error is 1.025 units.

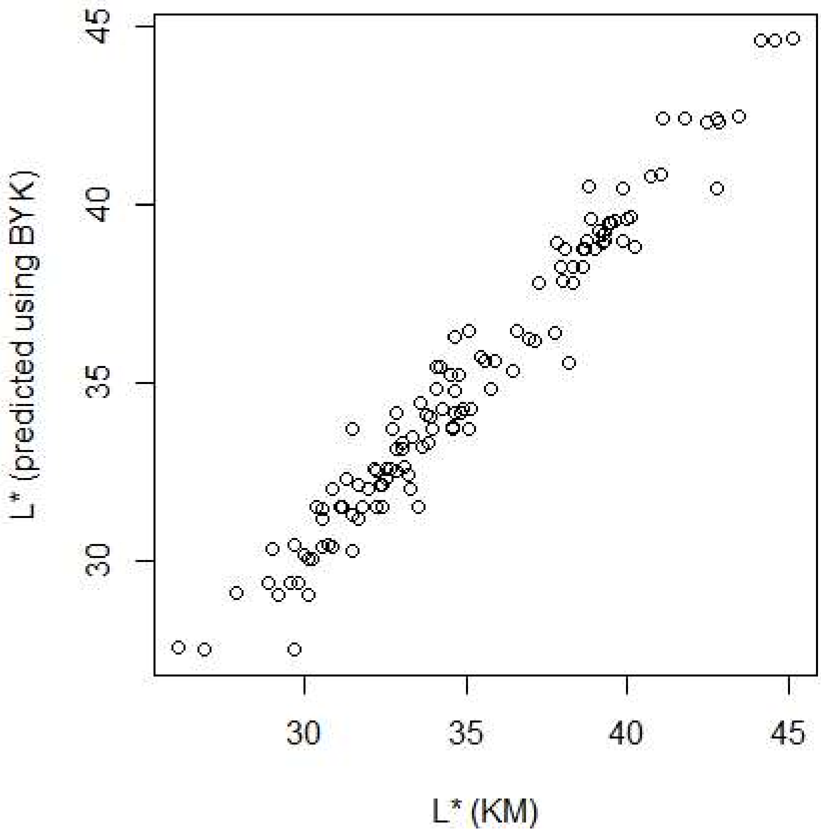


Figure 24: L* measurements on the KM machine and their predictions using BYK observations

Observations: a*

The a* observations are largely similar to those for L* measurements. Table 15 shows the red-green contrast to vary significantly across the sites and the spots at each site. Also the engraving and background differ in their a* measurements, to varying extents at each site and each spot. Allowing for these effects, however, the BYK measurement of a* is a very strongly significant predictor of the KM measurement of a*. The relationship of measurements from the two machines also differs at different spots.

Table 16 : Analysis of variance table for predicting KM measurements of a* from BYK measurements of a*.

Source of variation	df	SS	MS	F	p
site	6	430.3	71.7	501.3	0.00000008
spot	14	64.2	4.6	3.8	0.009
engraving	1	61.2	61.2	247985.9	0.001
engraving × site	6	158.5	26.4	73.2	0.00002
engraving × spot	14	54.5	3.9	4.2	0.006
a	1	10.5	10.5	21.8	0.00003
a × site	6	0.9	0.1	0.3	0.935
a × spot	14	16.8	1.2	2.5	0.012
a × engraving	1	0.0002	0.0002	0.0005	0.982
a × engraving × site	6	2.2	0.4	0.7	0.613
a × engraving × spot	14	13.0	0.9	1.9	0.051
error	41	19.8	0.5		

Figure 25 shows that the KM measurements can be modelled fairly accurately using site and spot and their interactions with BYK measurements and engraving information. The value of R^2 is again 0.96 and the residual standard error is 0.75 units.

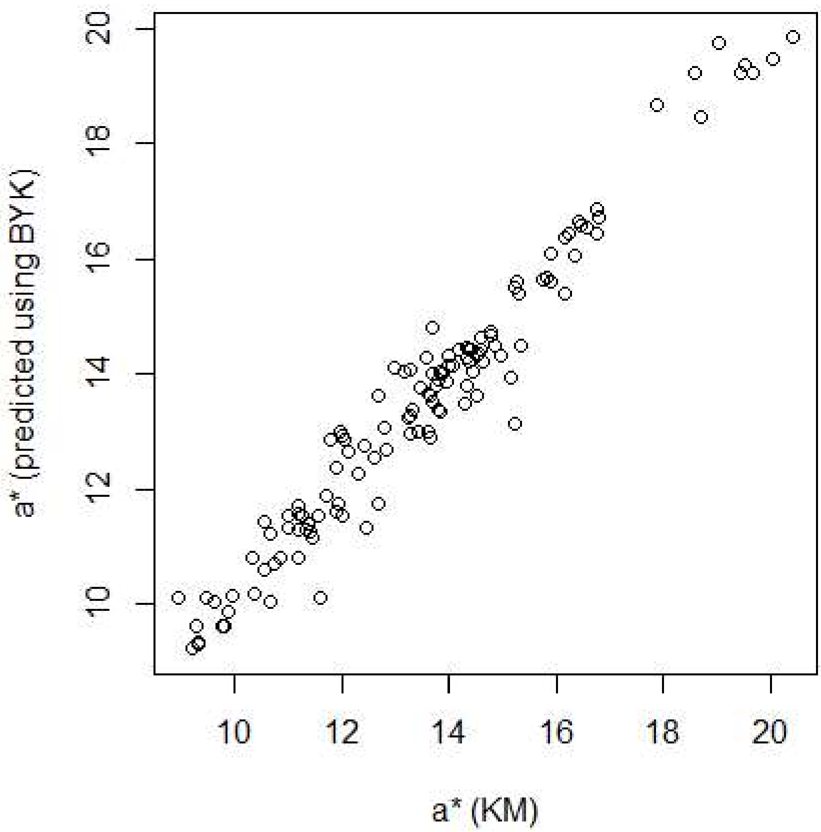


Figure 25: a* measurements on the KM machine and their predictions using BYK observations

Observations: b*

The results for b* are less clear-cut. Figure 26 shows the yellow-blue contrast to vary significantly across the sites and between background and engraving, with this difference varying at different sites and different spots at each site. Allowing for these effects, there is some evidence that the BYK measurement of b* predicts the KM measurement of b*, but stronger evidence that this effect varies at different spots. A model including both these effects is chosen (though the BYK measurements are less informative for yellow-blue contrast than they were for lightness or red-green contrast).

Table 17: Analysis of variance table for predicting KM measurements of a* from BYK measurements of a*

Source of variation	df	SS	MS	F	p
site	6	244.9	40.8	130.4	0.000004
spot	14	94.3	6.7	2.3	0.067
engraving	1	636.4	636.4	55768.4	0.003
engraving × site	6	248.2	41.4	46.7	0.00009
engraving × spot	14	44.3	3.2	5.0	0.002
b	1	4.4	4.4	3.7	0.062
b × site	6	1.9	0.3	0.3	0.952
b × spot	14	41.2	2.9	2.5	0.013
b × engraving	1	0.01	0.01	0.01	0.923
b × engraving × site	6	5.3	0.9	0.7	0.622
b × engraving × spot	14	8.8	0.6	0.5	0.903
error	41	49.2	1.2		

Figure 26 shows the KM measurements can be modelled fairly accurately using the chosen model. The value of R^2 is 0.95 and the residual standard error is 1.01 units.

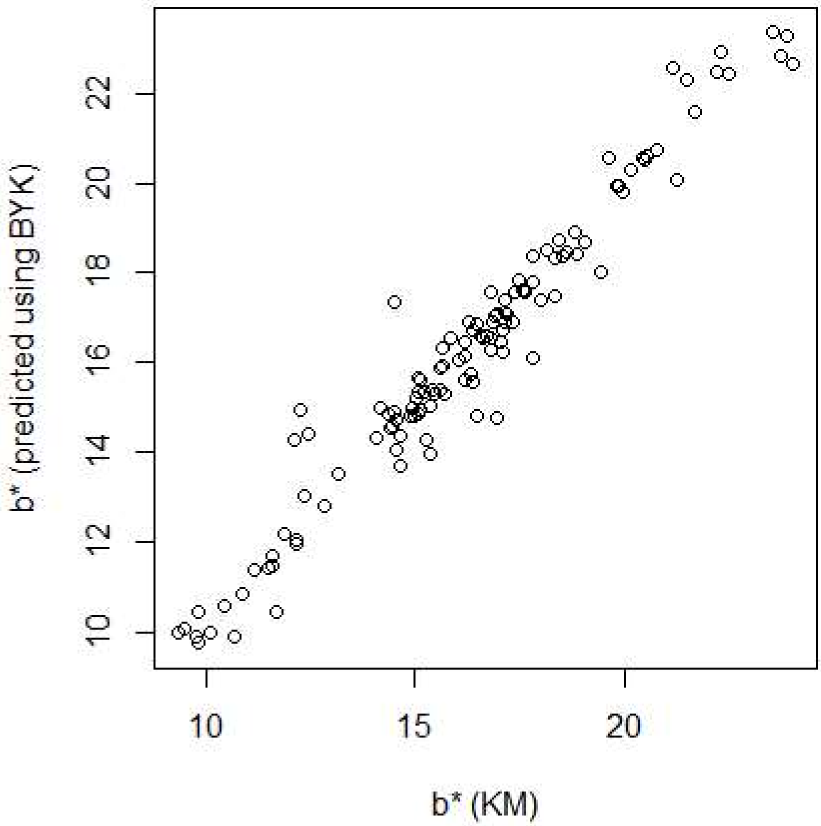


Figure 26: b* measurements on the KM machine and their predictions using BYK observations.

5. Conclusions

The measurements made in August 2013 continue the annual collection of ΔE colour measurements since 2004. Together, they provide an opportunity to observe whether any consistent trends have emerged in the annual colour change measurements. Variance in the data at some sample spots continue to suggest measurements are influenced by surface roughness (which affects spectrophotometer placement), and surface colour heterogeneity.

Site averaged colour change values at the southern test sites were not consistently different to those at the northern control sites, with most sites displaying relatively stable colour differences, with any slight changes being comparable between the Southern and Northern sites. Therefore the current indication is there was no consistent perceptible colour change over the period 2004–13 at either the control or test sites.

The colour measurements collected thus far may be used as a baseline measurement against which to compare future measurements in the short or long term, and are a valuable and independent evaluation of changes in rock surface colouration on the Burrup Peninsula. The continued annual colour change measurements into the future will provide further opportunity to observe whether there is any evidence of colour change.

6. Spectral Mineralogy

6.1 Reflectance spectroscopy

Reflectance spectroscopy is now available as a field tool for geologists through the development of portable instruments like the Analytical Spectral Device (ASD) FieldSpecPro field spectrometer. These systems measure diagnostic mineral spectral features that are particularly suitable for quantitative analysis of many geological materials. Some of the advantages of the technique include little sample preparation (if any), and rapid measurement (around 1 s) though the measurement is restricted to the sample's surface (< 50 µm).

CSIRO has been involved in the development of reflectance spectroscopy research (Ramanaidou et al., 2008 and references within) techniques for characterising iron ore, gold, bauxites, mineral sands, talc, lateritic nickel and asbestos. Using field reflectance spectrometry, the mineralogy of the samples can be characterised on the basis of key spectral features.

Reflectance spectroscopy, the analysis of reflected light, between 400 and 2500 nm is now a proven technique for mineral analysis in both the laboratory and in the field. Reflectance spectroscopy has been used intensely to characterise weathering minerals such as iron oxides and clay minerals. The most common iron oxides minerals (hematite, maghemite and goethite) have broad absorptions between 400 and 1000 nm (visible and near infrared or VNIR), whereas OH-bearing minerals such as phyllosilicates, inosilicates as well as carbonates and sulphates show narrow absorption features between 1000 to 2500 nm (short wave infrared or SWIR). The combination of these wavelength ranges provides a step forward towards quick and accurate mineral characterisation.

The Analytical Spectral Device (ASD) FieldSpec Pro covers the spectral range 400-2500 nm with a spectral resolution of 3 nm at 700 nm using 3 detectors: a 512 element Si photodiode array for the 400-1000 nm range and two separate, TE cooled, graded index InGaAs photodiodes for the 1000-2500 nm range. The input is through a1.4 m fibre optic. The average scanning time to acquire a spectrum is 1 second. There are two ways of operating the ASD, it consists of either using (1) an external source of light (sun or artificial) or (2) an internal source of light. The absolute measurements are obtained using a white reference plate that reflects 100% of the light in the 400 to 2500 nm wavelength range. For this study, the second option for lighting was used as it eliminates any external light interference.

6.2 Spectral Results for 2004-2013

6.2.1 PICTURES AND SPECTRA

For each site, the description and interpretation include:

- A digital image of the engraving with the location of the measurements: spot 1, 2, and 3 and, from 2013 a new spot labelled 4 for both engraving and background. The new 4th engraving and background analysis spots have been added to the photographs.
- Comparison of the average spectra for the engravings and background for each of the three (or four) spots between 2004 and 2013.
- The following pages present photographs of the monitored petroglyphs at each site, showing the sampling points of engravings and background rock, and the average colour measurements that were recorded at these points each year.

Figure 27: ASD FieldSpecPro and Konica Minolta CM-700dspectrophotometer operating on petroglyphs in the Burrup Peninsula (2013)

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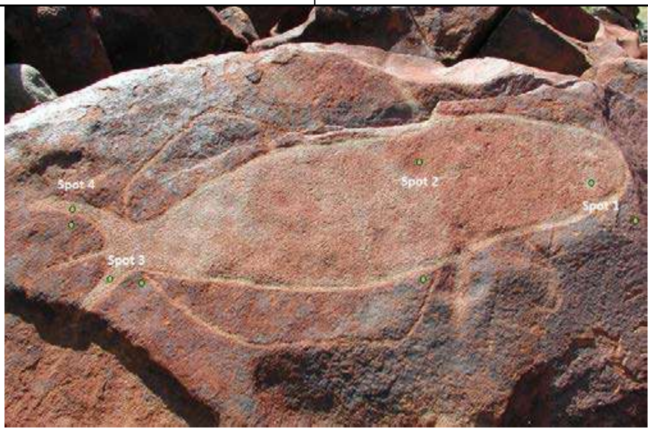
<tr><td>Site 1</td><td colspan="2">
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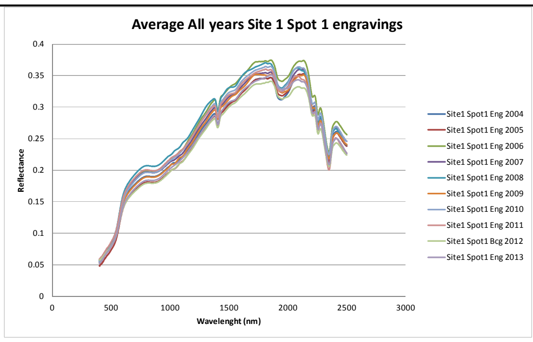
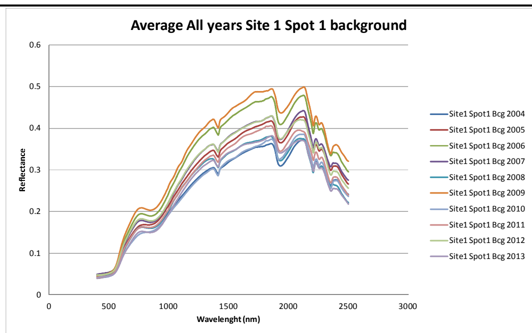
Spot 1</td><td>
</td><td>
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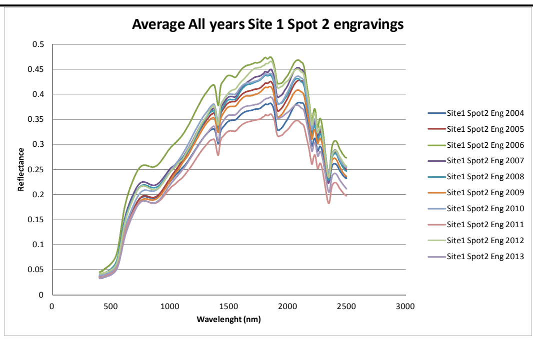
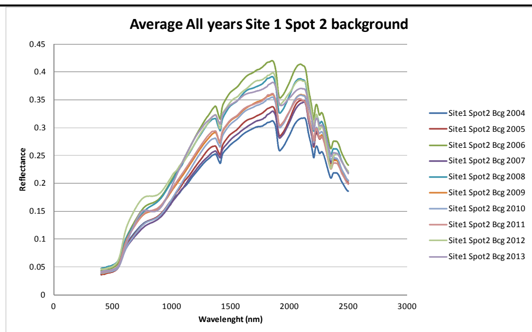
Spot 2</td><td>
</td><td>
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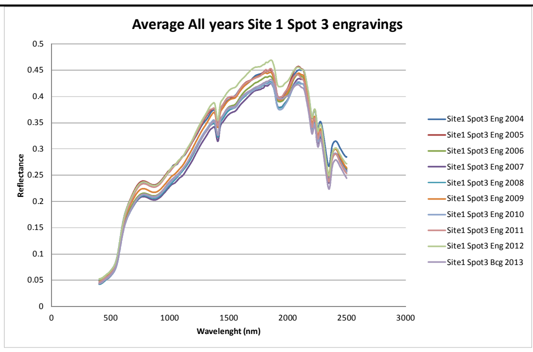
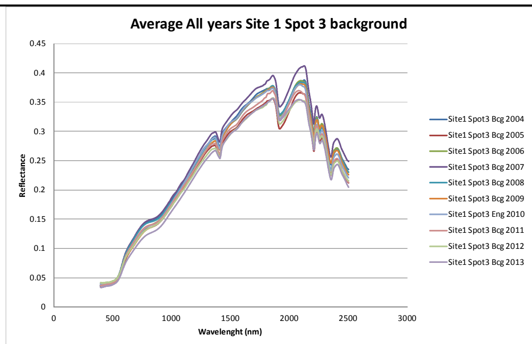
Spot 3</td><td>
</td><td>
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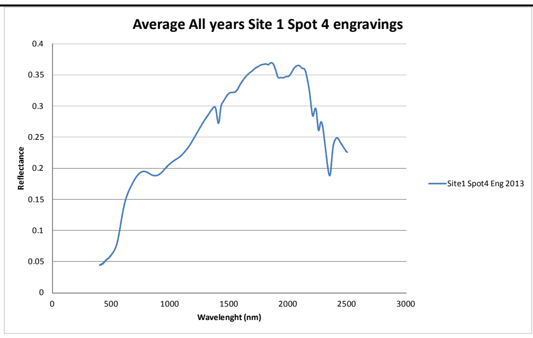
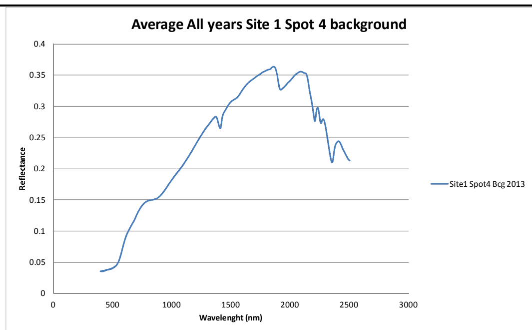
Spot 4</td><td>
</td><td>
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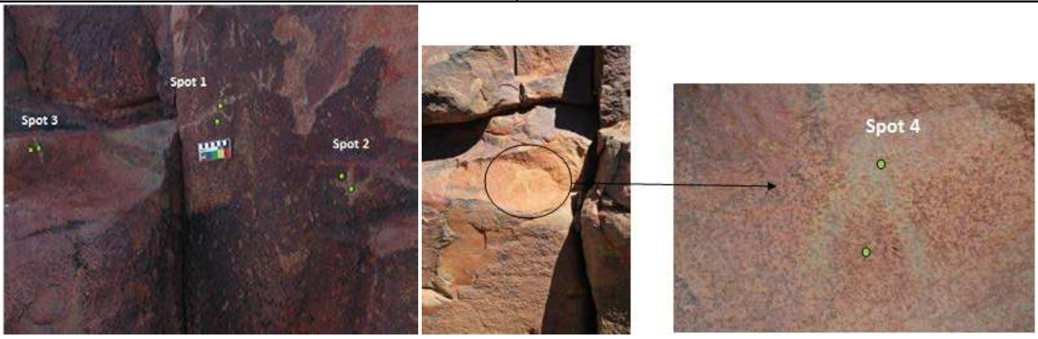
<tr><td>Site 2</td><td colspan="2">
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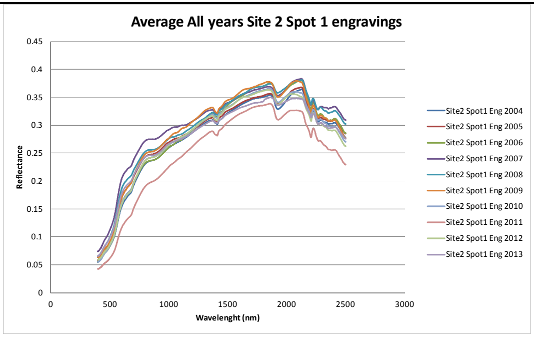
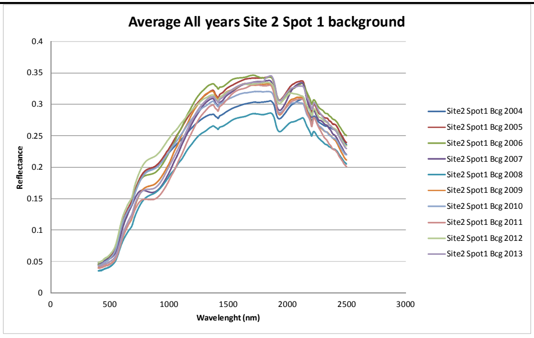
Spot 1</td><td>
</td><td>
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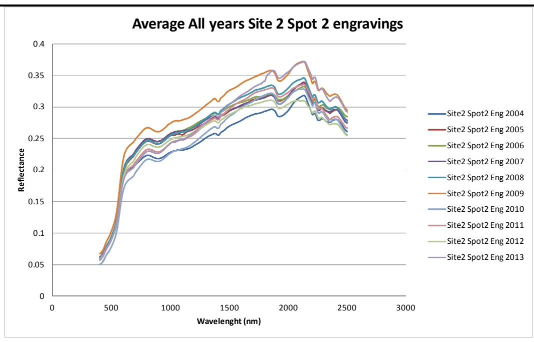
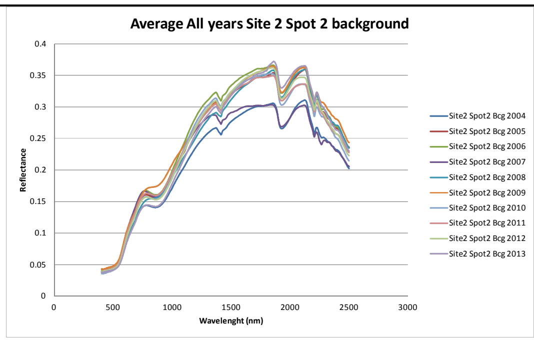
Spot 2</td><td>
</td><td>
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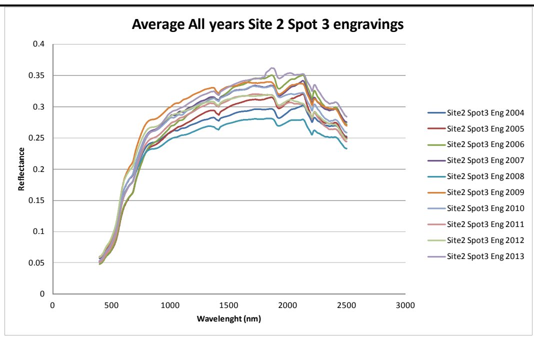
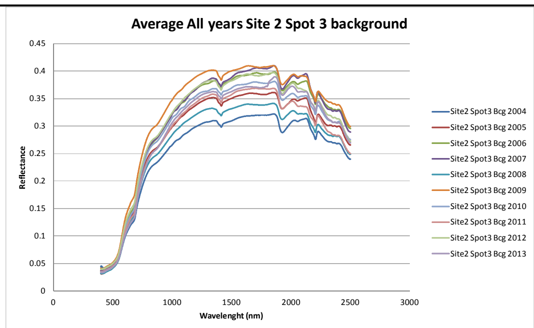
Spot 3</td><td>
</td><td>
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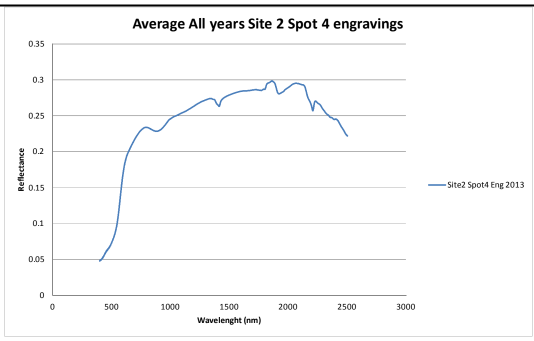
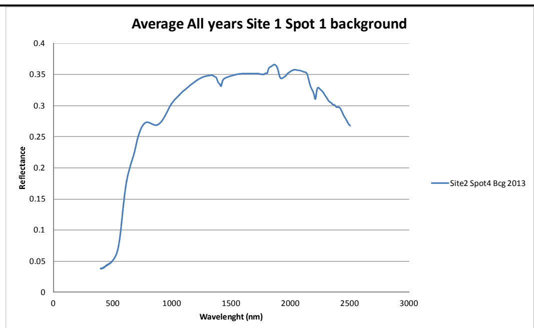
Spot 4</td><td>
</td><td>
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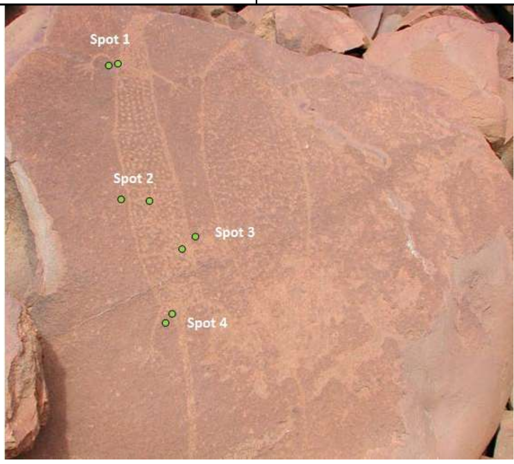
<tr><td>Site 4</td><td colspan="2">
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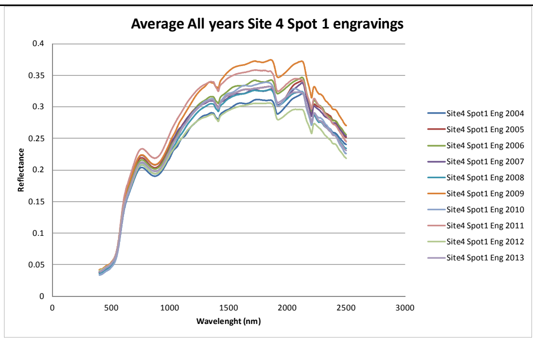
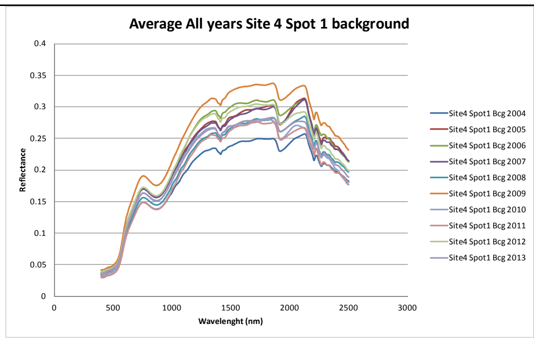
Spot 1</td><td>
</td><td>
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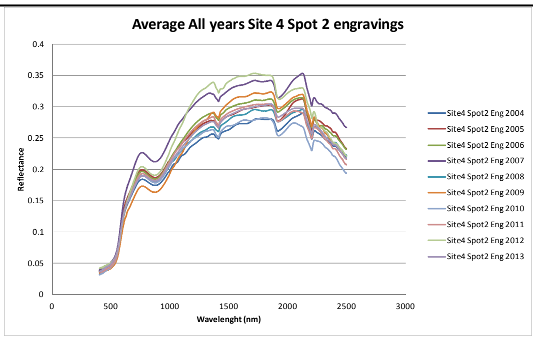
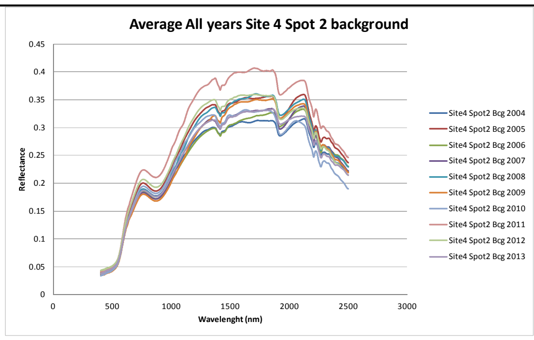
Spot 2</td><td>
</td><td>
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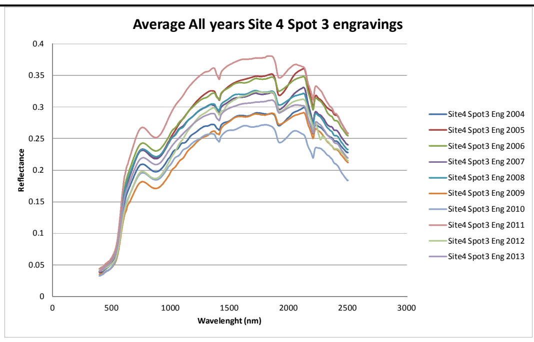
Spot 3</td><td>
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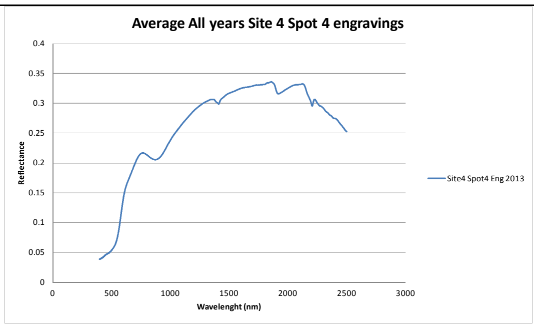
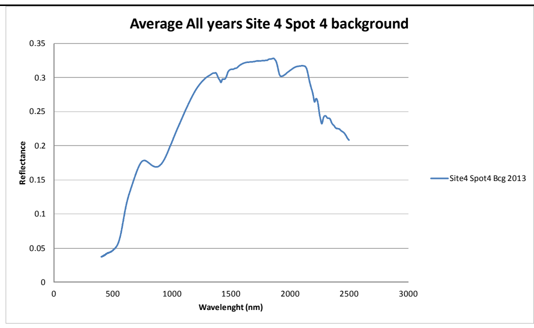
Spot 4</td><td>
</td><td>
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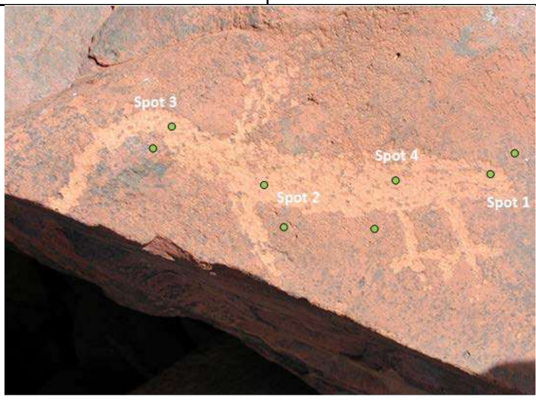
<tr><td></td><td colspan="2">
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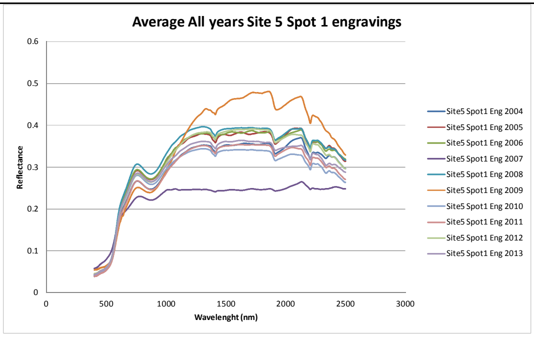
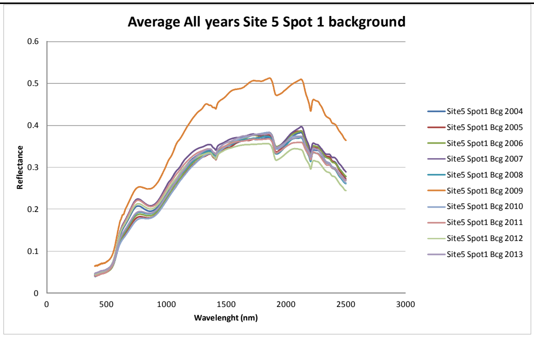
Spot 1</td><td>
</td><td>
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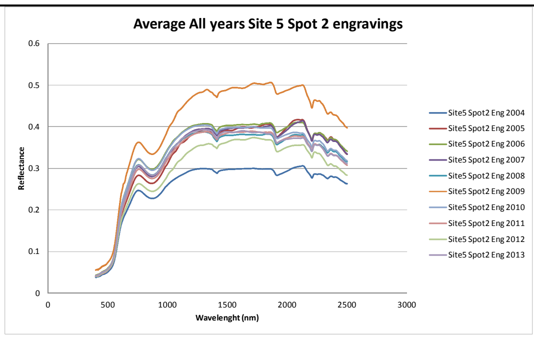
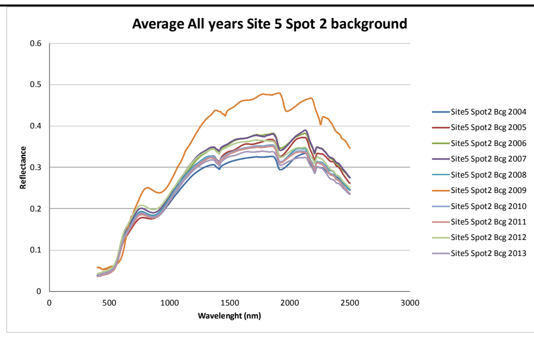
Spot 2</td><td>
</td><td>
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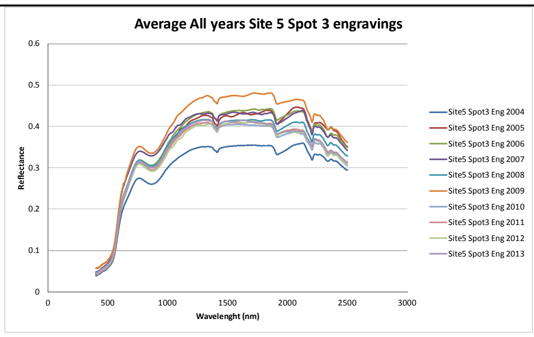
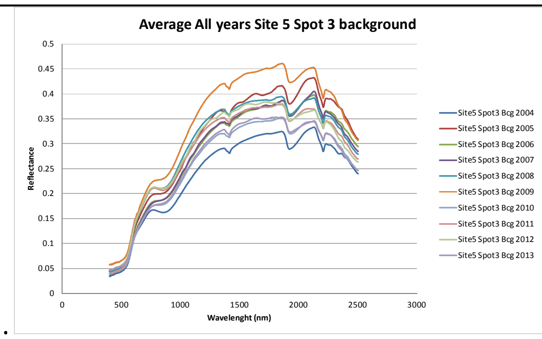
Spot 3</td><td>
</td><td>
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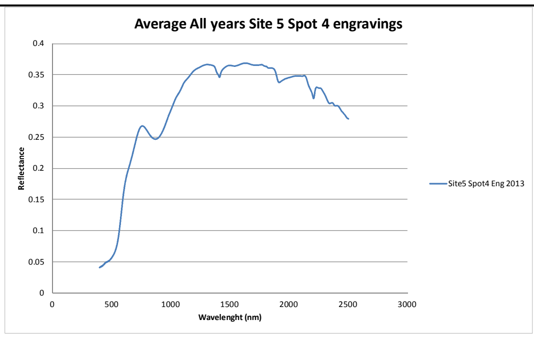
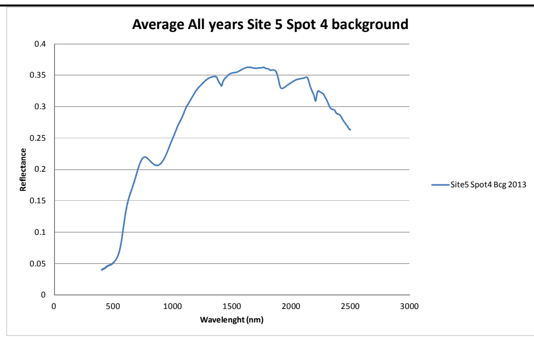
Spot 4</td><td>
</td><td>
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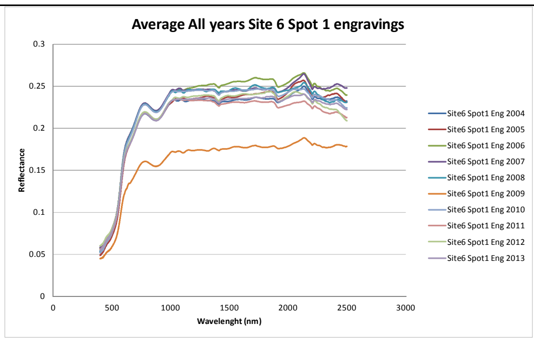
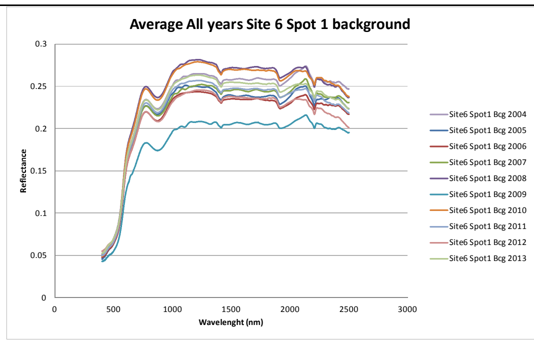
Spot 1</td><td>
</td><td>
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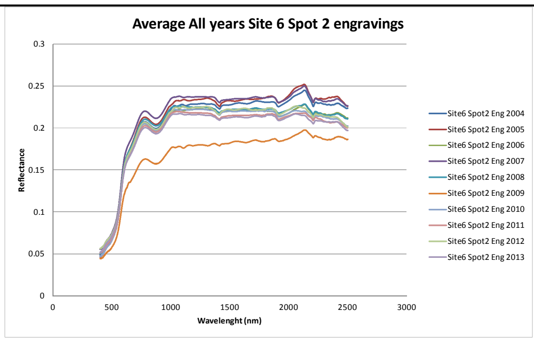
Spot 2</td><td>
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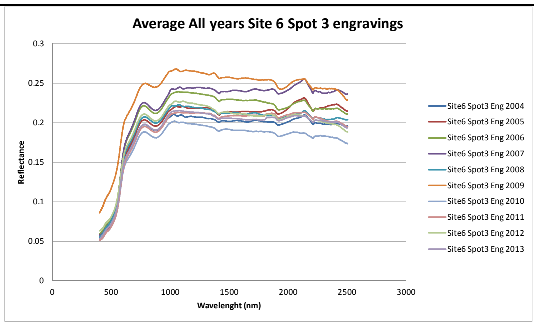
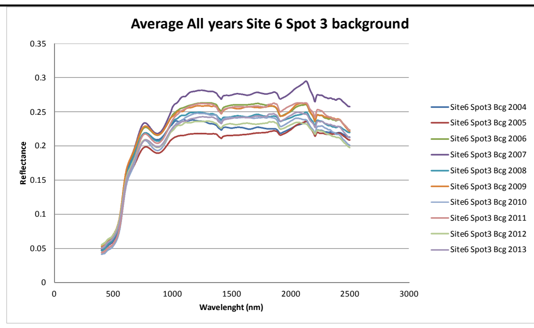
Spot 3</td><td>
</td><td>
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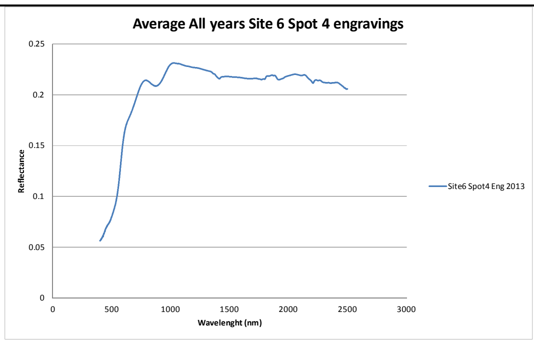
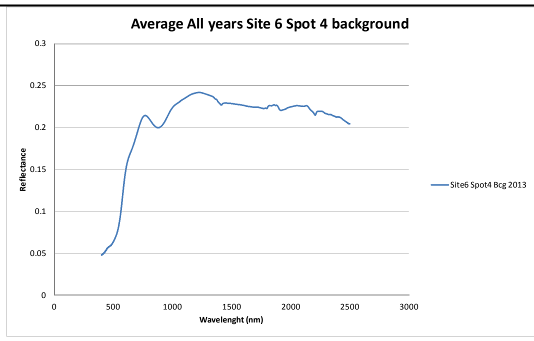
Spot 4</td><td>
</td><td>
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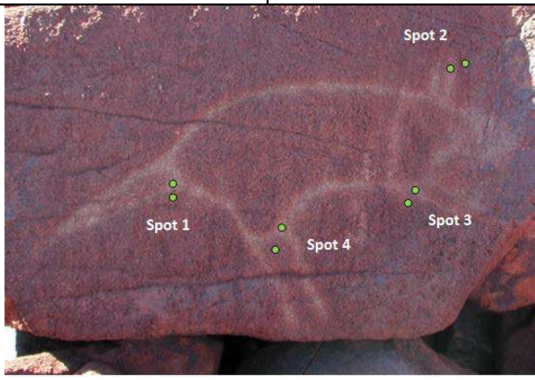
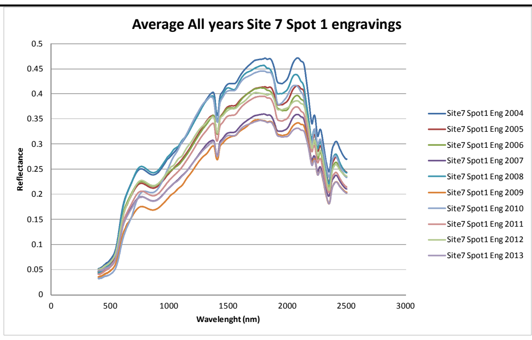
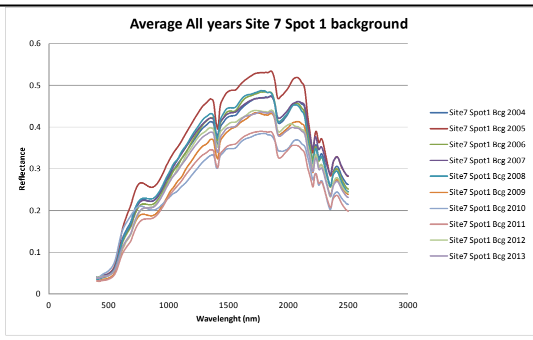
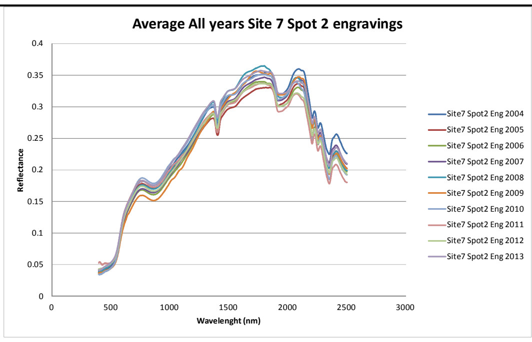
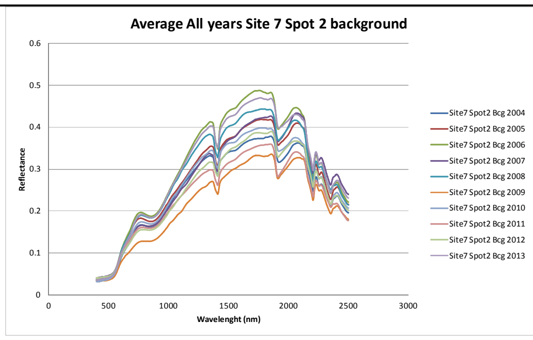
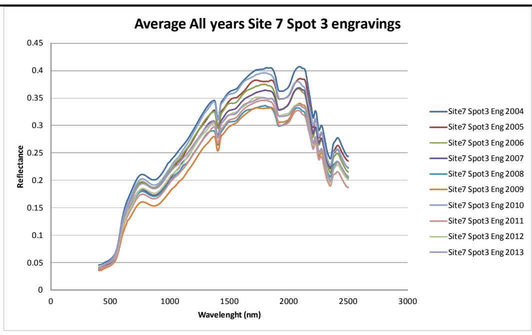
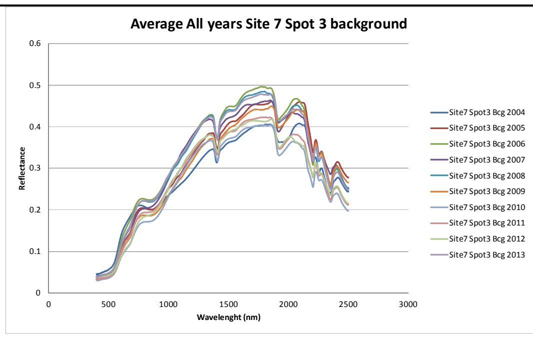
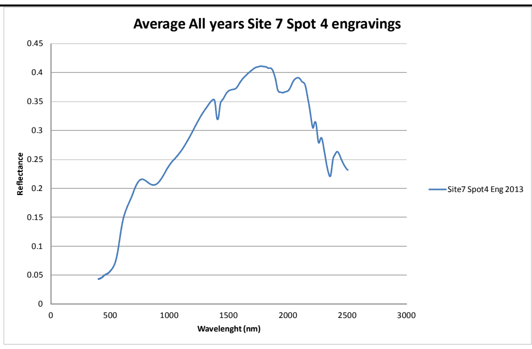
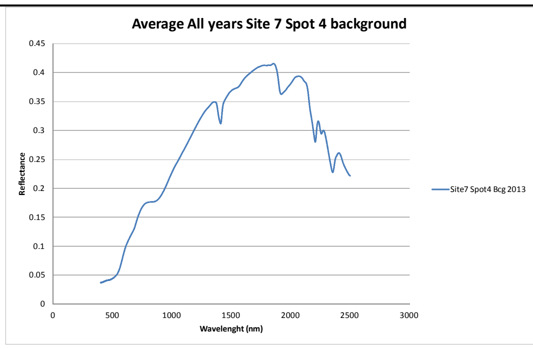
		
Site 7 Spot 1		
Site 7 Spot 2		
Site 7 Spot 3		
Site7 Spot 4		

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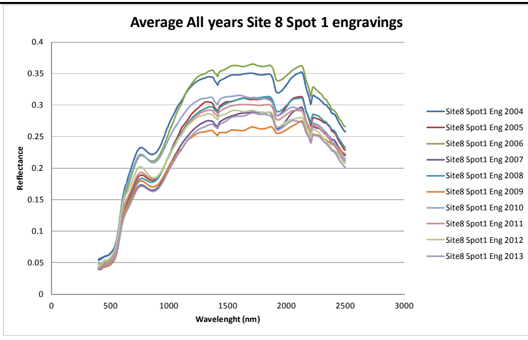
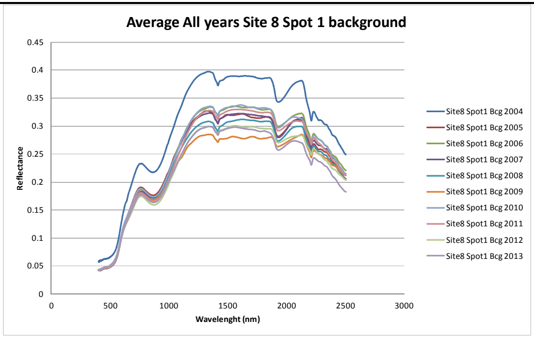
Spot 1</td><td>
</td><td>
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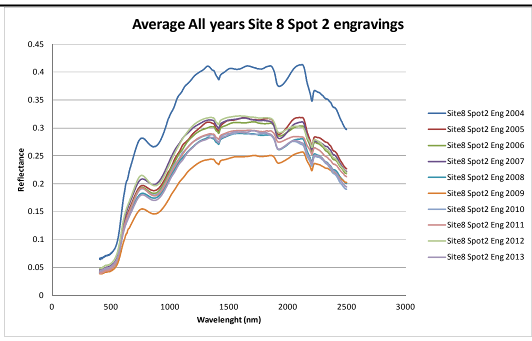
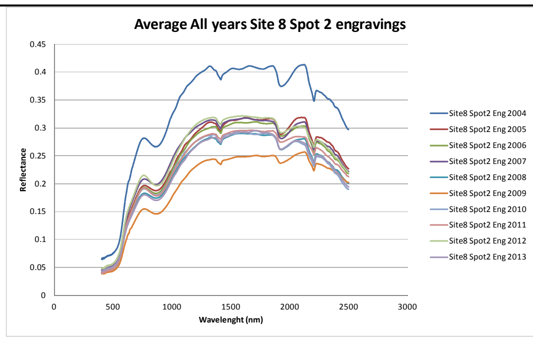
Spot 2</td><td>
</td><td>
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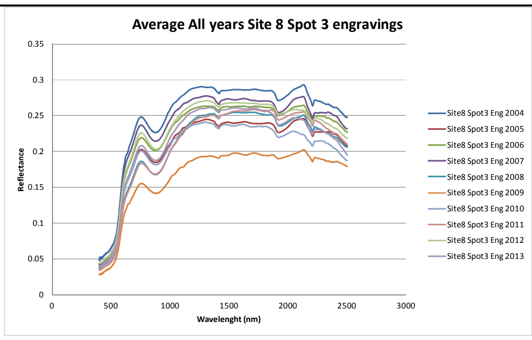
Spot 3</td><td>
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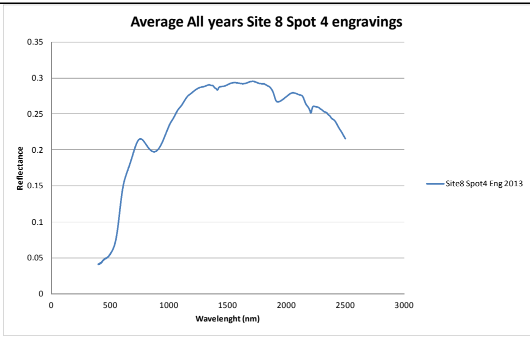
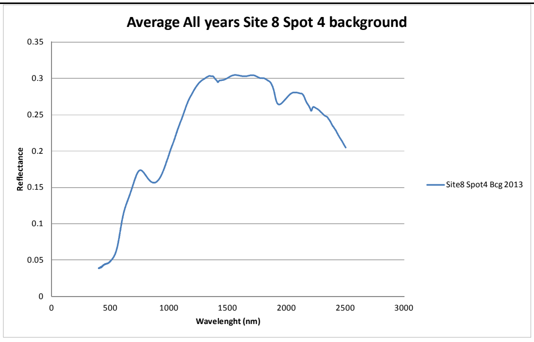
Site 8 Spot 4		

Figure 28: Digital image of the engraving with the location of the measurements (spot 1, 2, 3 and 4 for both engraving and background. Spot 4 measured from 2013). Comparison of the average spectra for the engravings and background for each of the three spots between 2004 and 2013.

6.2.2 STATISTICAL ANALYSES FOR THE ASD SPECTRA

Spectra were obtained from both the background and engraving at each of three spots at the seven sites on the Burrup peninsula, in each of the years from 2004-2013. The goal of the statistical analyses is to identify numeric trends in the data; an important follow-up step is to interpret the spectra and their trends to obtain physically meaningful information.

The spectra for the background of the engraving at Spot 2 of Site 6 for instance appear very similar across the ten years of observations (Figure 29). This is also true of the data for background and engraving at all spots on all sites.

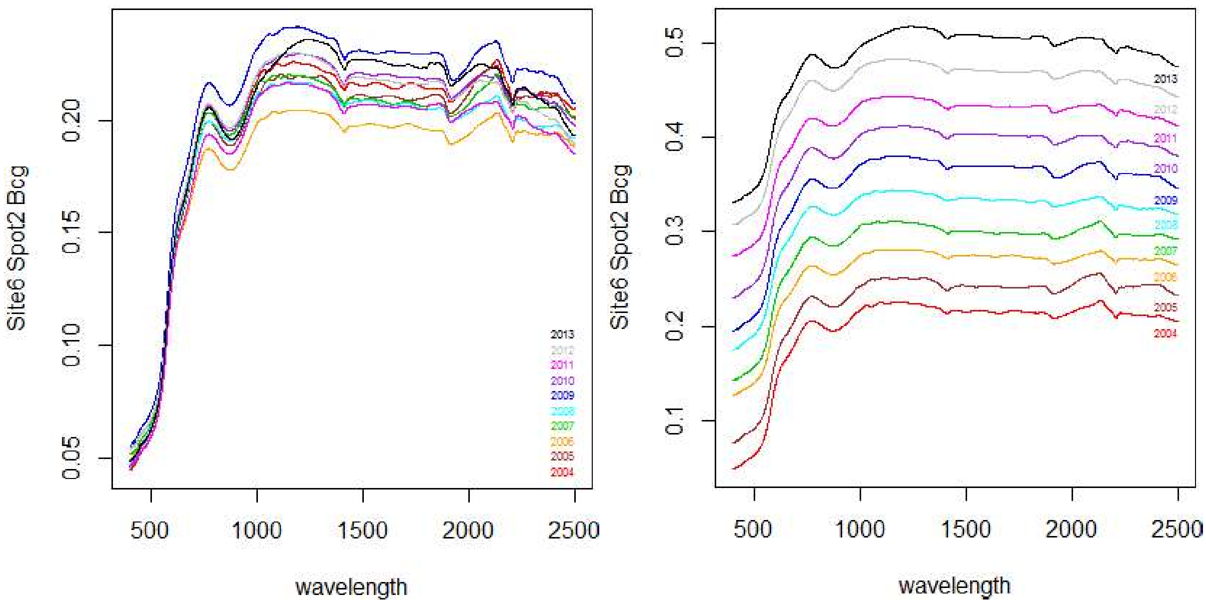


Figure 29 An example of the changes in spectra over time, plotted overlapping each other (left) and translated vertically to avoid overlap (right).

The slight changes in spectra can either be due to random machine error or represent a deterministic trend. The potential changes over time could be done for (1) the intensity of the spectrum at particular wavelengths, or, via (2) principal component analysis, for summary measures of the entire spectrum.

1. Intensity of the spectrum at particular wavelengths

The value of the spectrum in the trough at the 873 nm wavelength and at the peak at the 2129 nm wavelength shows that no consistent trend over time appears in these plots (Figure 30). The peak at 2129 nm is very marked in the year 2006 and it appears the lowest because that whole part of the spectrum is lower in 2006 than in other years, not because the peak was less marked in that year (Figure 30).

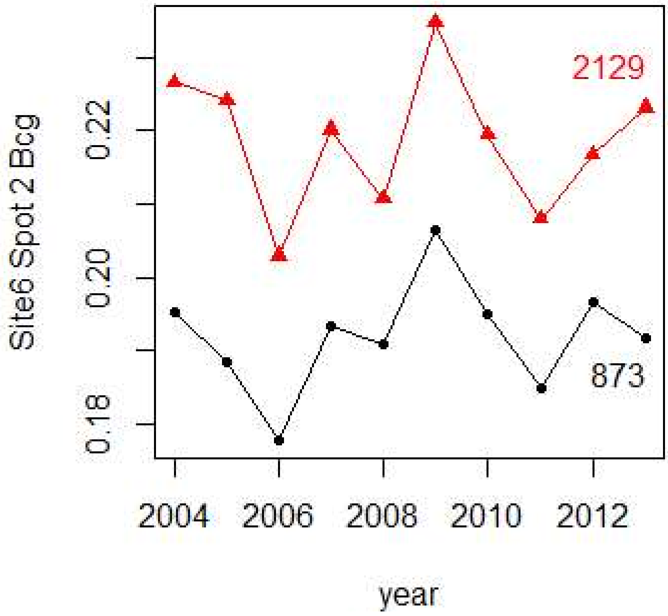


Figure 30 Values of the spectra at wavelengths 873 and 2129 (corresponding to one of the troughs and one of the peaks in Figure 29) for the background of the engraving at spot 2 of site 6.

2. The Principal component analysis (PCA) summarises the change in the entire spectrum.

The first principal component (PC1) for background or engraving on each spot at each site is an 'average' of the spectra measured over 2004-2013. The second principal component (PC2) highlights the direction of the most noticeable deviation from that average across the ten years of data. Similar analysis could be performed on the third principal component as most of the variation in the spectra is explained by these two components with 99.9 % (Figure 31). PC1 and PC2 respectively represent 99.7% and 0.2% of the variability (Figure 31). Each spectrum is scaled individually to have zero mean and unit variance, before the principal component analysis is conducted. Each spectrum can then be decomposed onto its principal components. This allows the variation over time to be summarised in only a few variables, so that it can be more easily visualised. The changes over time in the coefficients of the first two principal components in the decomposition of spectra at two different sites are plotted in Figure 32 for Site 1 Spot Background and Site 6 Spot 2 Background (All the 42 graphs produced are shown in Appendix B). Horizontal axis labels on the graphs show that the first principal component in each case accounts for over 98 % of the overall variation – none of them deviate far from the average for that spot and site.

If there was a systematic change in the spectra over time then there would be a systematic trend in the plots. Most of them, though, appear similar to Site 1 Spot Background, left plot in Figure 32; the scores on each principal component oscillate randomly, producing a trendless 'squiggle' indicating only random variations to and fro over the years.

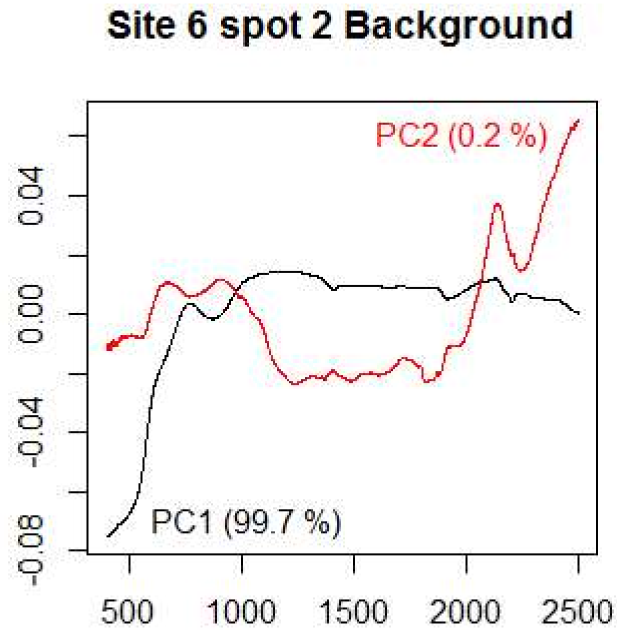


Figure 31 An example of the first two principal components, for the background of the engraving at spot 2 of site 6. Note that the vast majority of variation in the spectra – 99.7 % – is accounted for by the first principal component. The second principal component (0.2%) adjusts the first, for example accentuating the peak at wavelength 2129.

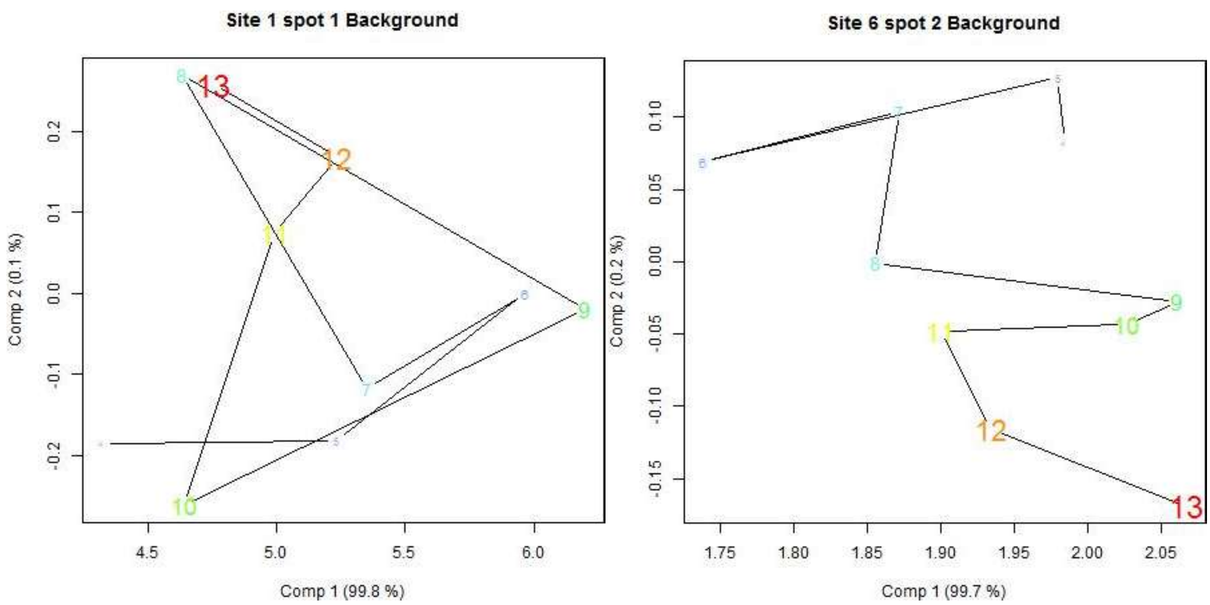


Figure 32 Score plot of the first two principal components of spectra recorded in the background of the engravings at spot 1 of site 1 (left) and spot 2 of site 6 (right). Data points are labelled 4-13, corresponding to the years 2004-2013 when data was recorded. (Labels for more recent data are displayed larger and in colours closer to red.)

For Site 6 Spot 2 Background (right plot in Figure 32), while oscillating from side to side, the line trends quite steadily downward, more recent data having more negative amounts of the second principal component indicating that the peak at wavelength 2129 is less emphasised in more recent data.

The physical meaning of any changes should be established. As noted above, the changes in spectra in Figure 29 appear slight; even a statistically significant trend may have no practical importance, if the effects are so small as to have no substantive effect on the composition of the rocks or the engravings.

An important caveat is that in such an extensive analysis a few false positives would be expected; on average one significance test in 20 will appear significant at the 5 % level even when there is no real effect at all. The analysis above essentially comprises 84 such tests, so about four false positives might be expected. Applying a Bonferroni correction to the 84 tests, results should be significant at the 0.06 % level in order to maintain a familywise error rate less than 5 %.

6.2.3 SPECTRAL PARAMETERS

Spectral parameters were extracted from the spectra and include:

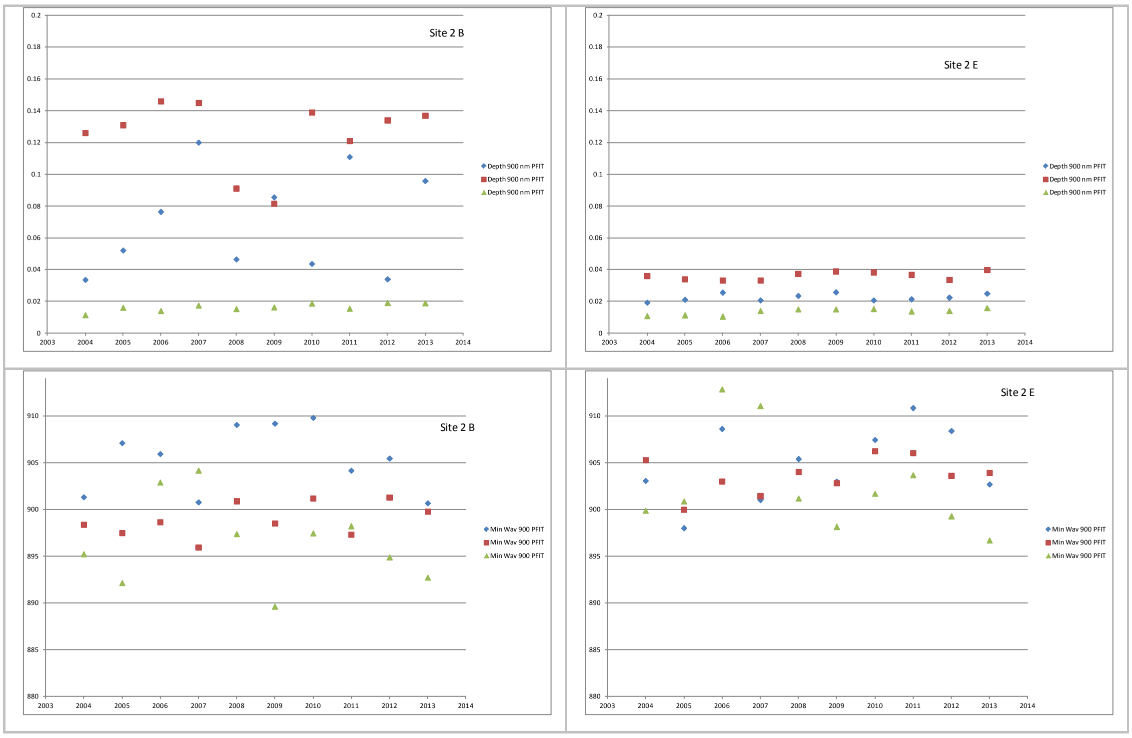
1. The depth (Depth 900 nm) and minimum wavelength (Min Wav 900 nm) of the large 900nm centred absorption providing information on the iron oxides
2. The depth of the chlorite absorption - Depth Chlorite (residual mineral from the fresh rocks)
3. The depth of the kaolinite (Depth Kaolinite) and, when present, gibbsite (Depth Gibbsite) absorptions (secondary minerals resulting from the weathering of the primary minerals)

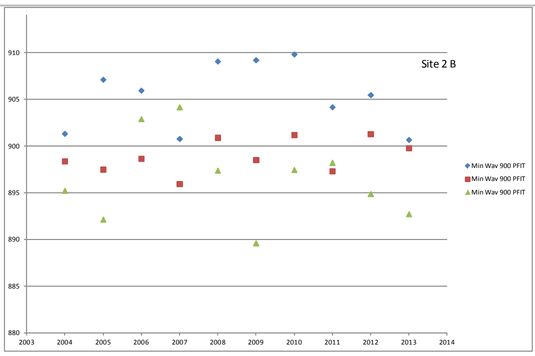
The statistical analysis of the 378 measurements is shown in Table 18 below.

Table 18: Statistical analysis of spectral parameters (434 measurements)

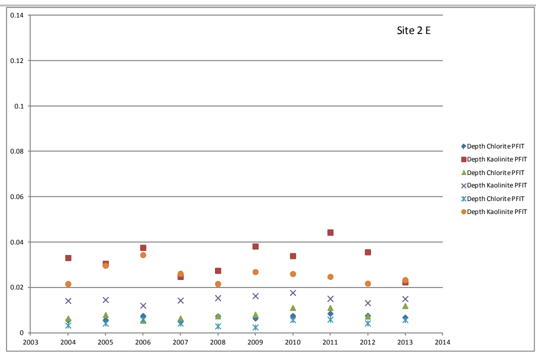
	Average	Standard Deviation	Minimum	Maximum
Depth 900 nm	0.102	0.04	0.01	0.18
Min Wav 900 nm	893.3	5.98	881.7	912.86
Depth Chlorite	0.023	0.033	0	0.124
Depth Kaolinite	0.040	0.017	0.003	0.115
Depth Gibbsite	0.003	0.004	0	0.024


Site 1 B
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT
Site 1 E
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT
Site 1 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT
Site 1 E
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT
Site 1 B
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT
Site 1 E
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT

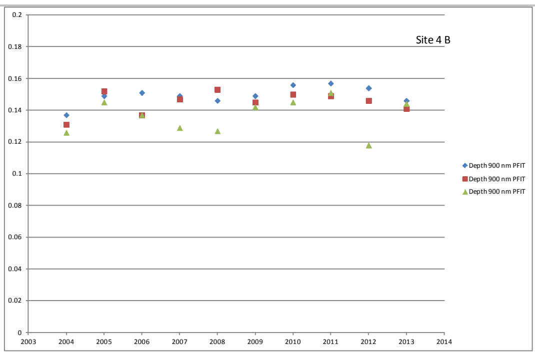

Site 2 B
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT
Site 2 E
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT
Site 2 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT
Site 2 E
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT



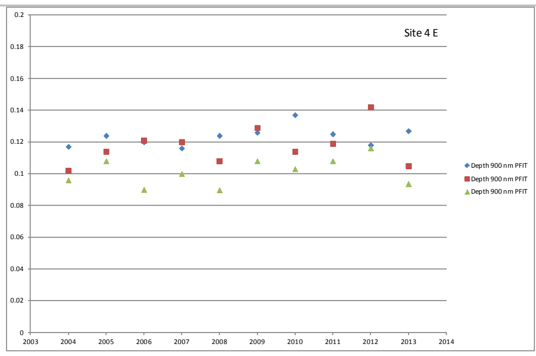
Site 2 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT



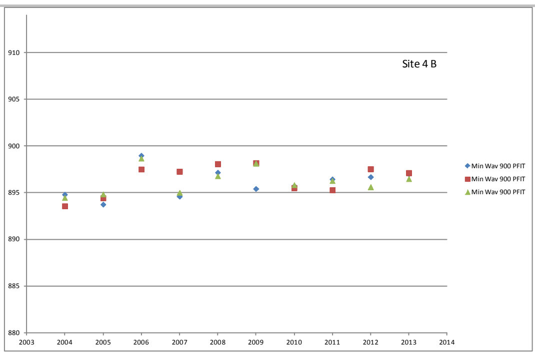
Site 2 E
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT



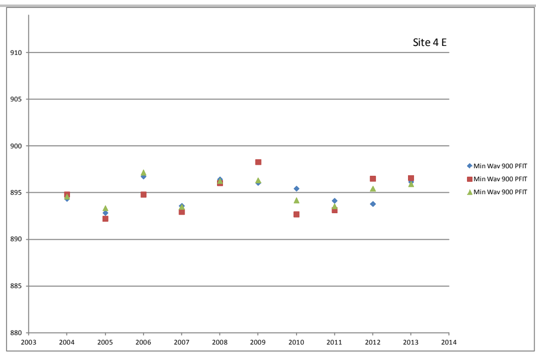
Site 4 B
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT



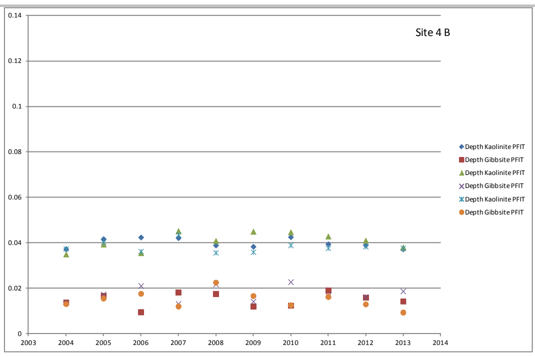
Site 4 E
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT



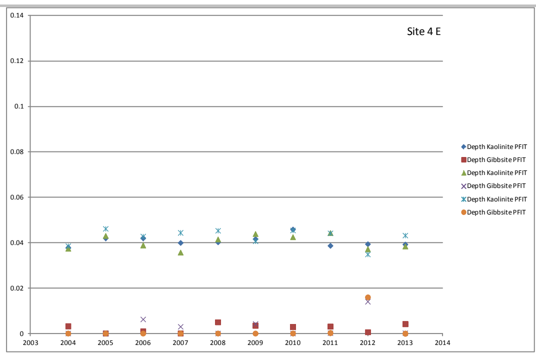
Site 4 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT



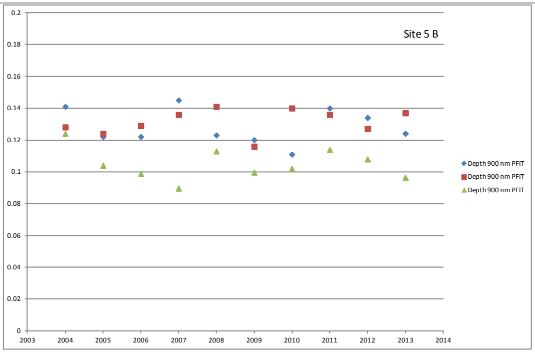
Site 4 E
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT

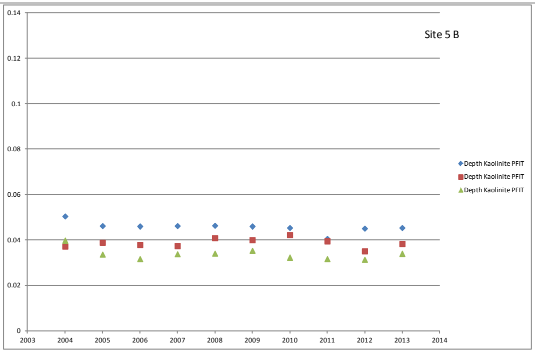


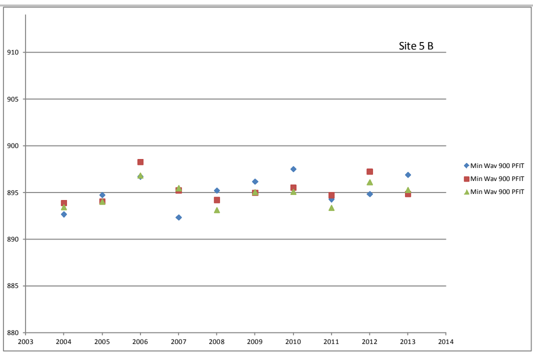
Site 4 B
Depth Kaolinite PFIT
Depth Gibbsite PFIT
Depth Kaolinite PFIT
Depth Gibbsite PFIT
Depth Kaolinite PFIT
Depth Gibbsite PFIT

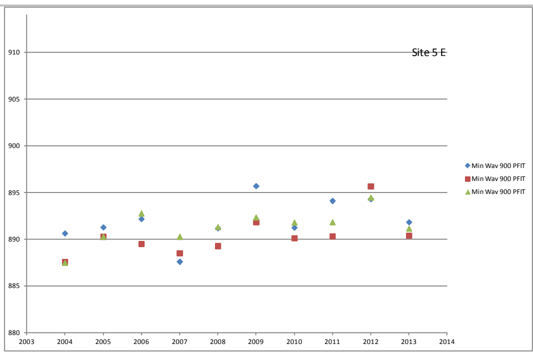


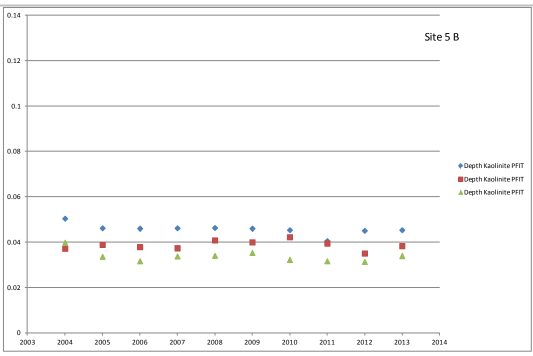
Site 4 E
Depth Kaolinite PFIT
Depth Gibbsite PFIT
Depth Kaolinite PFIT
Depth Gibbsite PFIT
Depth Kaolinite PFIT
Depth Gibbsite PFIT

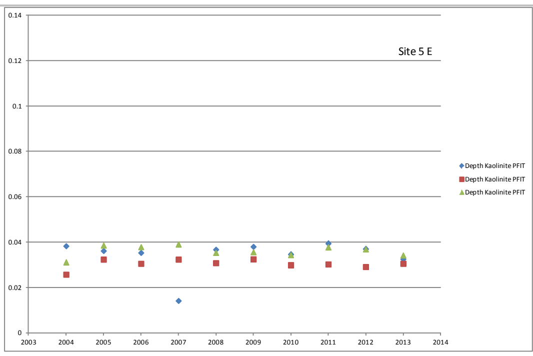

Site 5 B
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT

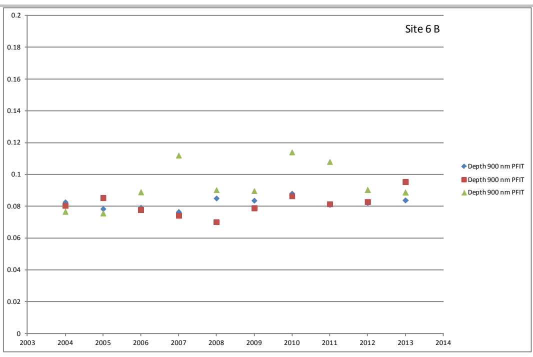

Site 5 B
Depth Kaolinite PFIT
Depth Kaolinite PFIT
Depth Kaolinite PFIT


Site 5 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT


Site 5 E
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT


Site 5 B
Depth Kaolinite PFIT
Depth Kaolinite PFIT
Depth Kaolinite PFIT


Site 5 E
Depth Kaolinite PFIT
Depth Kaolinite PFIT
Depth Kaolinite PFIT


Site 6 B
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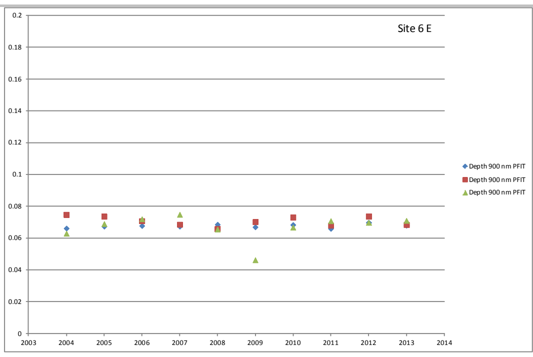
Depth 900 nm PFIT
Depth 900 nm PFIT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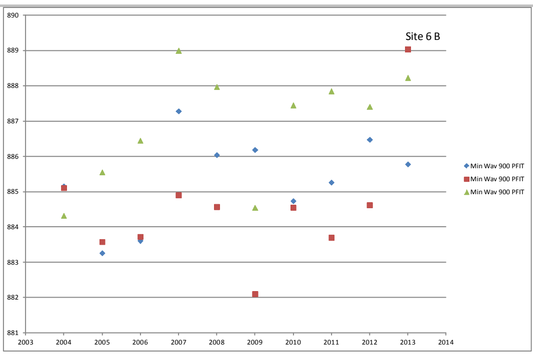
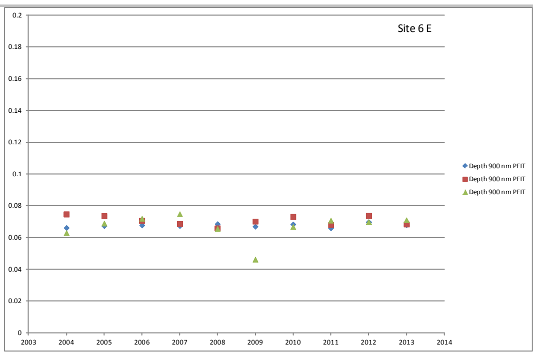
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT


Site 6 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT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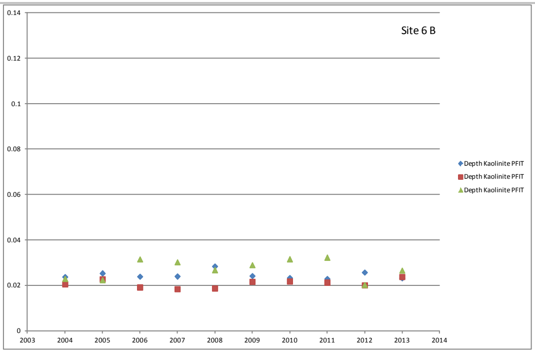
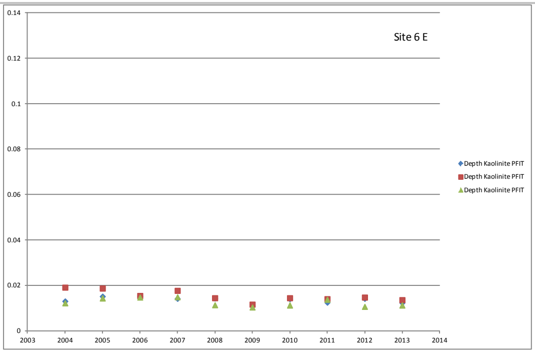
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT


Site 6 B
Depth Kaolinite PFIT
Depth Kaolinite PFIT
Depth Kaolinite PFIT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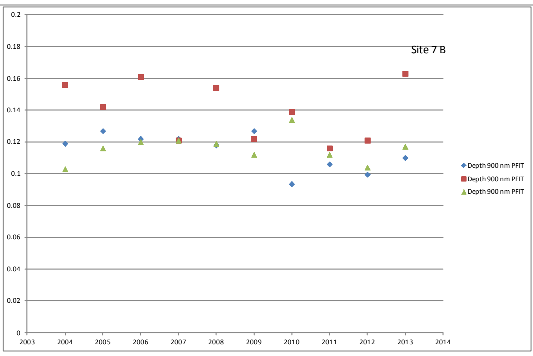
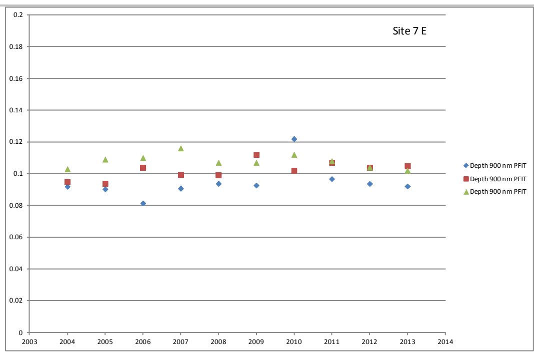
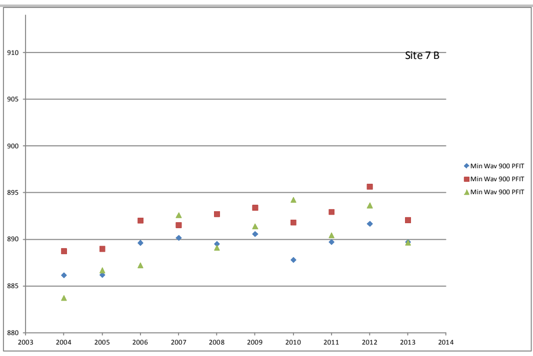
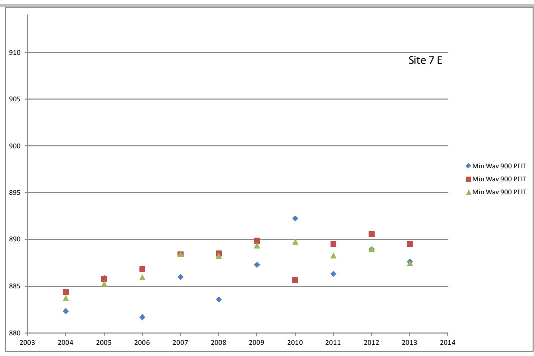
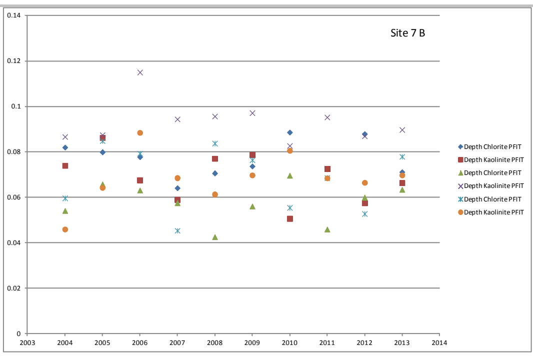
Depth Kaolinite PFIT
Depth Kaolinite PFIT
Depth Kaolinite PFIT

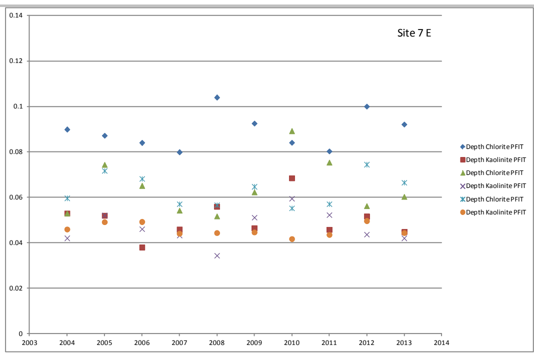

Site 7 B
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT


Site 7 E
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT


Site 7 B
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT


Site 7 E
Min Wav 900 PFIT
Min Wav 900 PFIT
Min Wav 900 PFIT


Site 7 B
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT
Depth Chlorite PFIT
Depth Kaolinite PFIT


Site 7 E
Depth Chlorite PFIT
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Depth Chlorite PFIT
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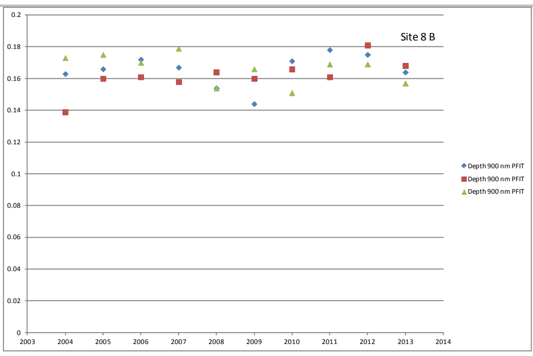
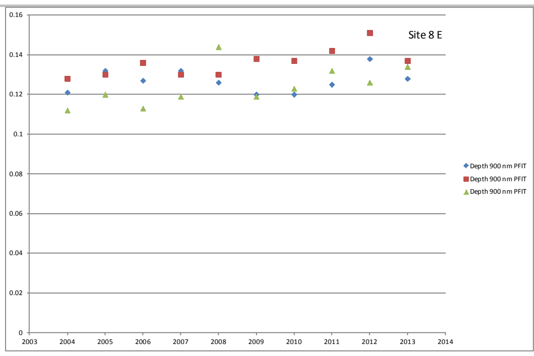
Depth Kaolinite PFIT


Site 8 B
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT


Site 8 E
Depth 900 nm PFIT
Depth 900 nm PFIT
Depth 900 nm PFIT

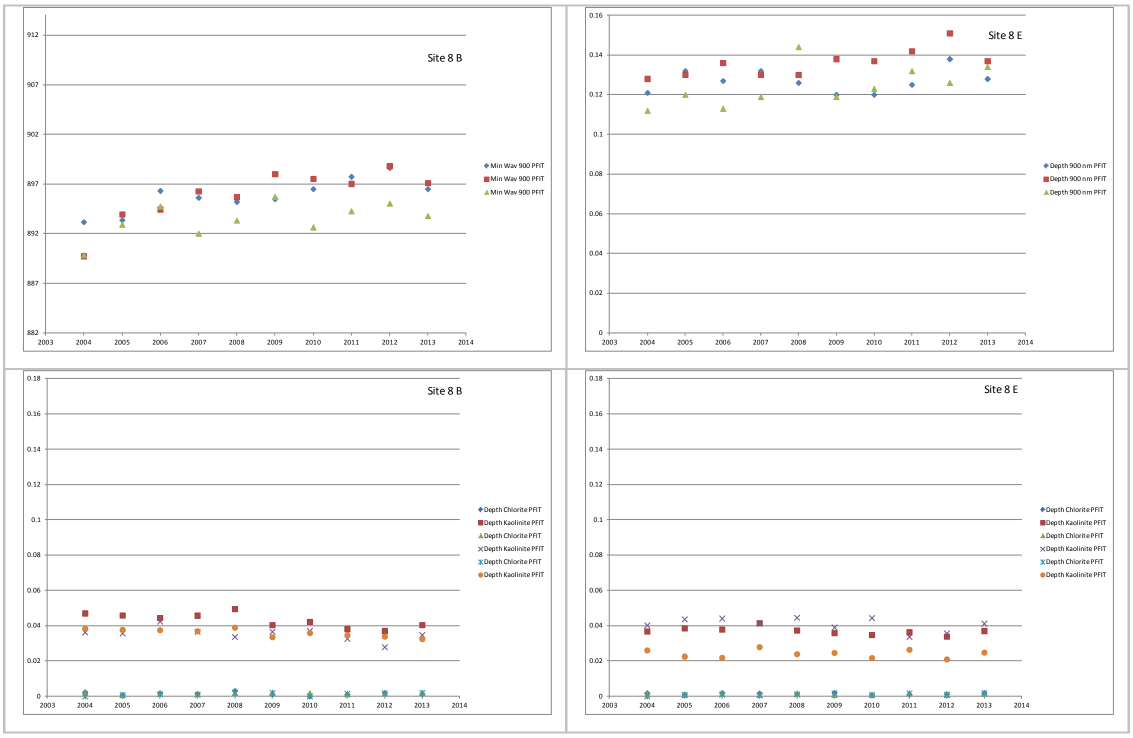


Figure 33: Spectral parameters for all sites

6.2.4 RESULTS FROM THE SPECTRAL PARAMETERS

The spectral parameters extracted from the reflectance spectra of all sites and, all backgrounds and engravings, combined with the statistical analysis show that the small changes are within expected variations. For Site 6 Spot 2 Engravings and Background apart from a slight increase of the minimum wavelength in 2013 for the background (Figure 34), no significant trend was observed.

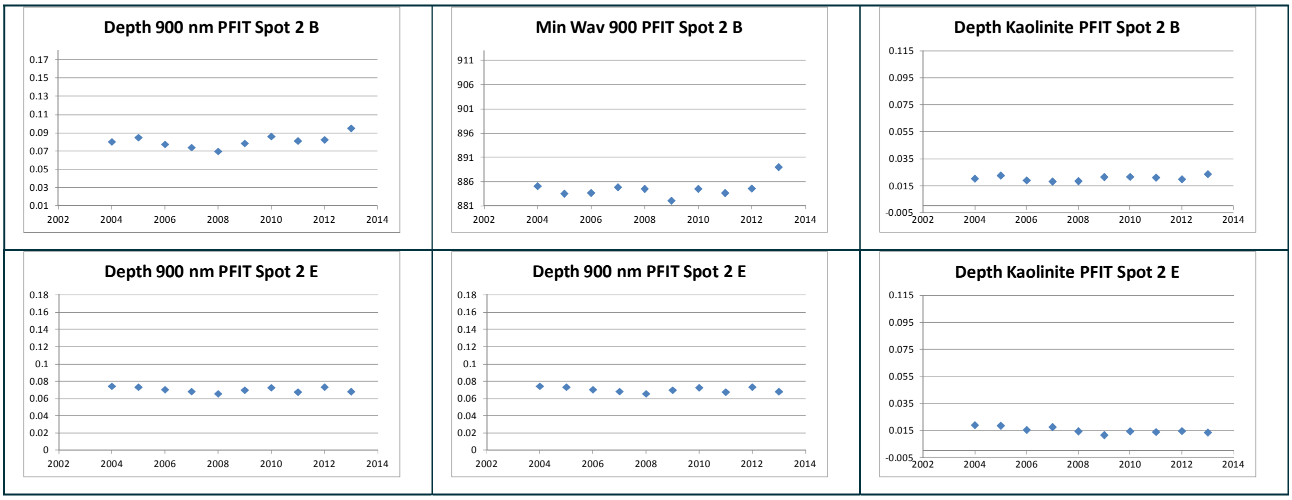


Figure 34 Spectral parameters for Site 6 Spot 2 Background (B) and Engraving (E). The scale for each parameter is guided by the minimum and maximum values for all sites.

7. Comparison between spectrophotometer and ASD for the colour difference between the background and engraving

The comparison of the colour difference between engravings and background using the ASD and spectrophotometer at all sites are shown in Figure 35. In most cases, the average ΔE values obtained from each of the techniques are comparable, and the gradients of the linear fit of the average data show good correlation between the techniques.

The most obvious discrepancy between data collected using the two techniques can be observed at Site 7. The ASD results show ΔE values that are relatively stable over the data collection period, while the spectrophotometer results show a slight decrease in ΔE values with time. Site 7 had the roughest surface and the larger measurement used for ASD may have been more effective at negating any instrument placement effects on colour measurements. Colour heterogeneity of the sample area was also discussed as a possible cause of measurement variance, and the smaller sample port of the spectrophotometer would make the measurements more likely to be impacted by this aspect.

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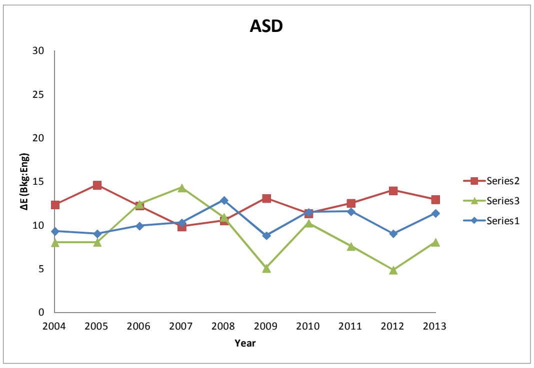
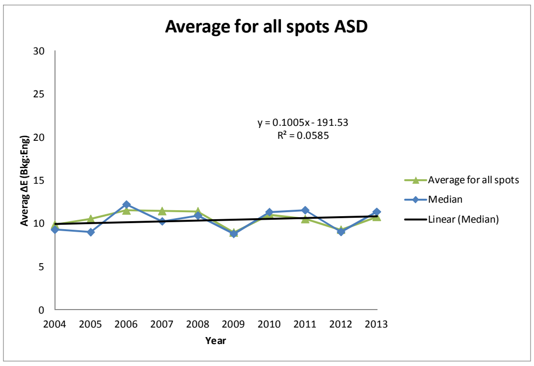
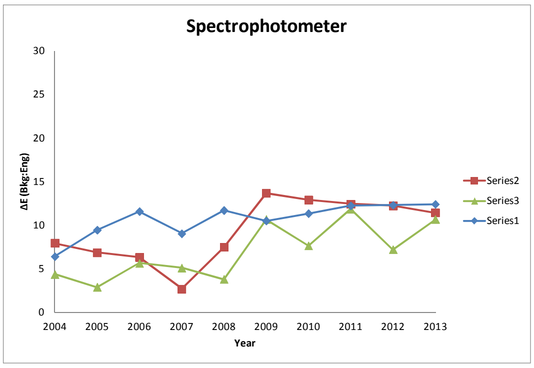
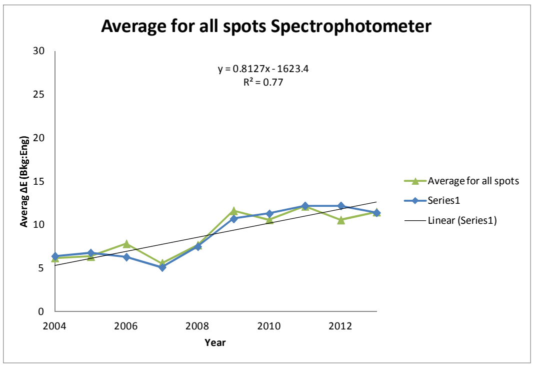
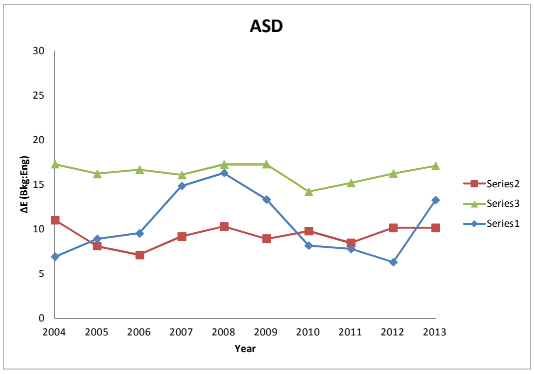
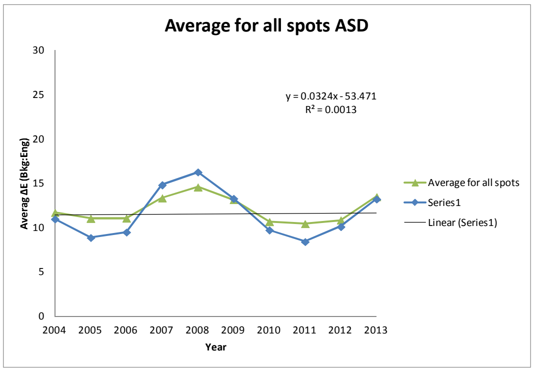
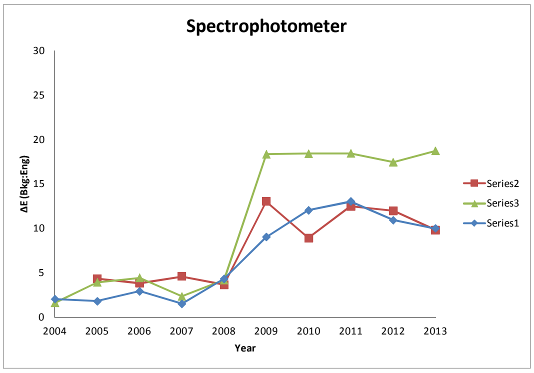
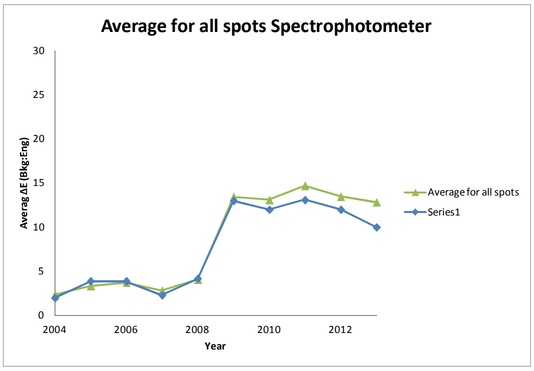
Dolphin
Island</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">Site 2
Gidley
Island</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
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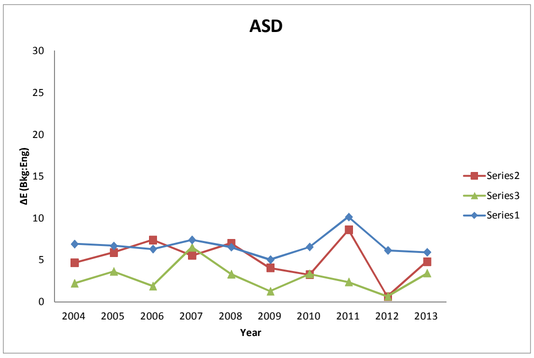
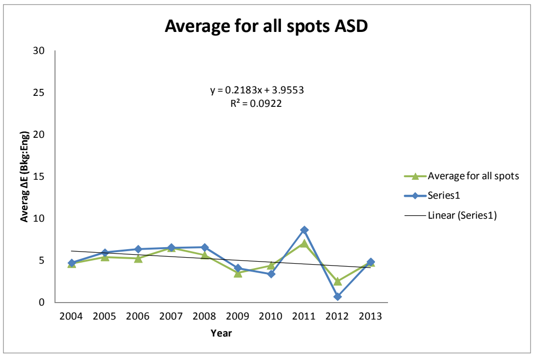
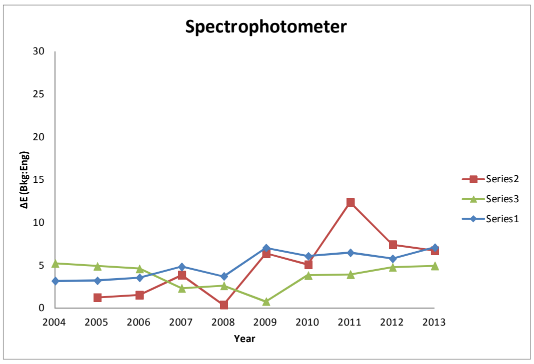
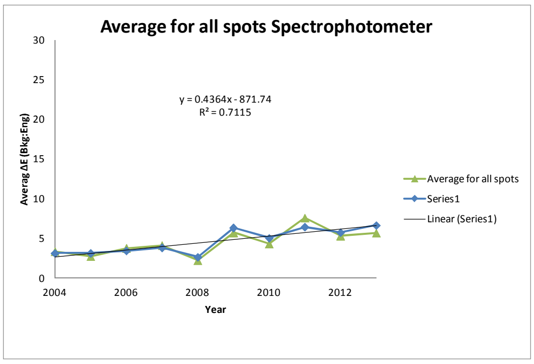
Site 4

Woodside



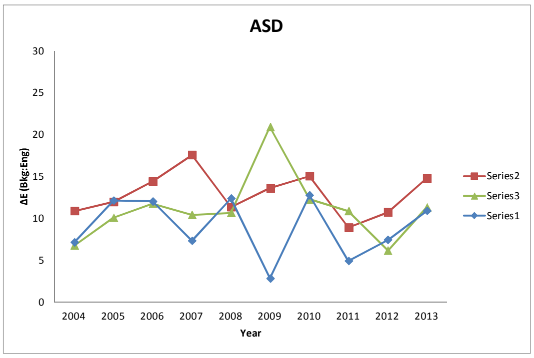


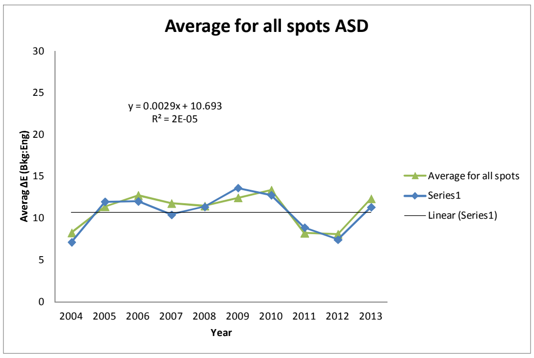


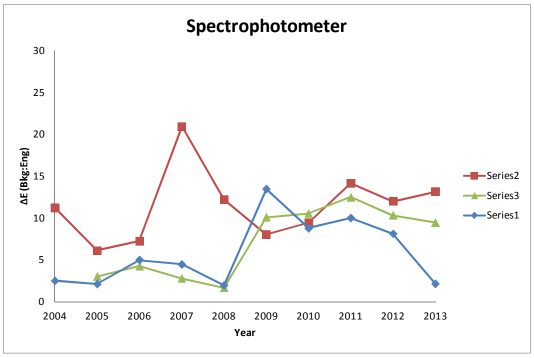


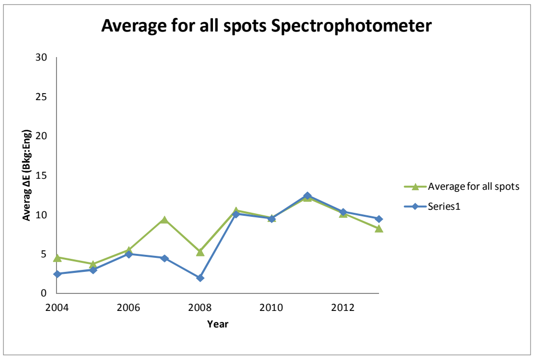
Site 5

Burrup Rd

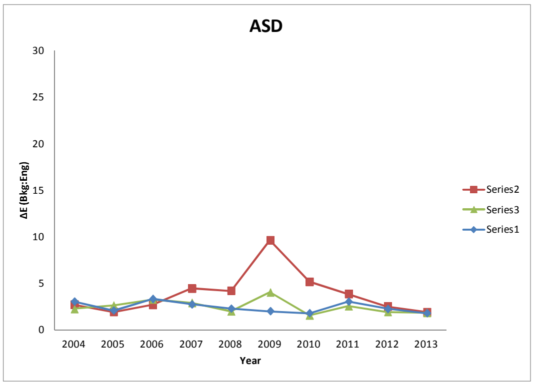


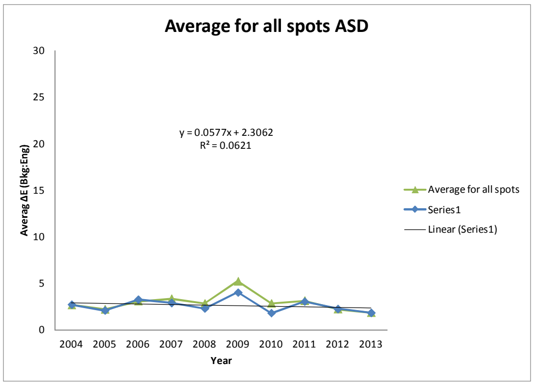


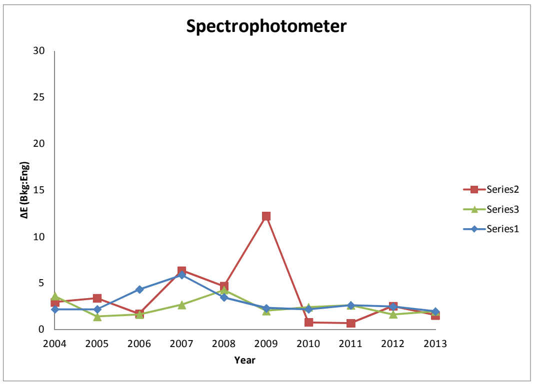


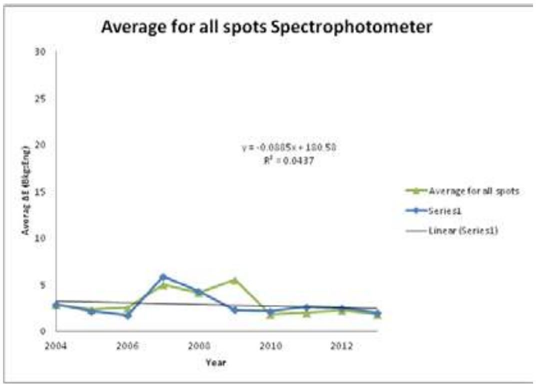


Site 6 Water Tanks

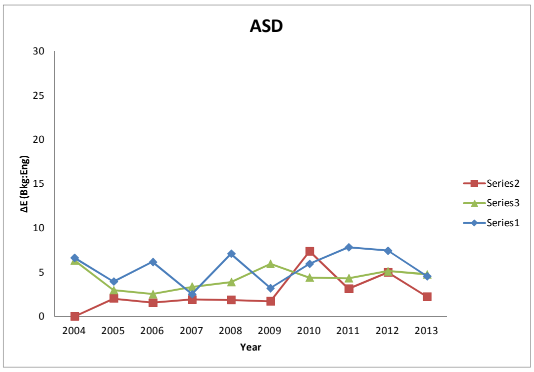


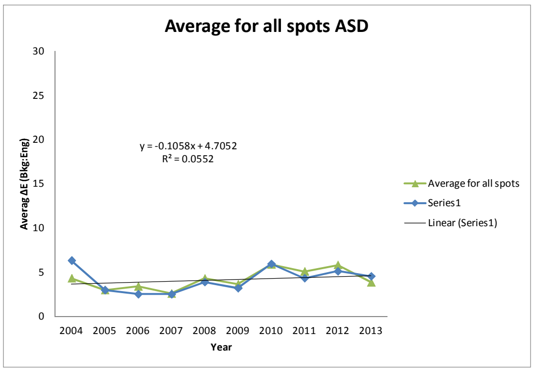


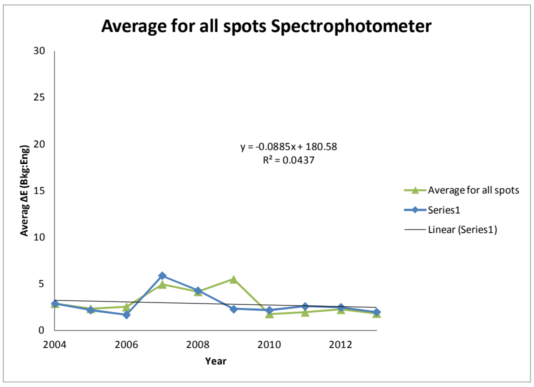


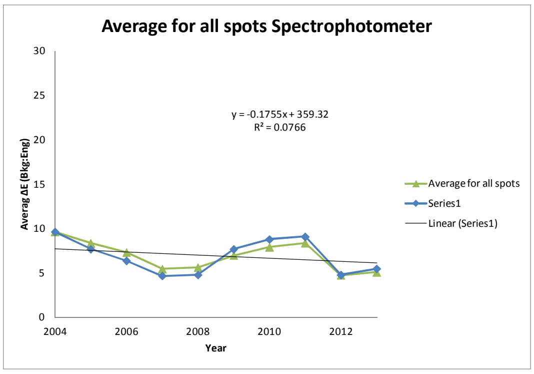


Site 7 Deep Gorge

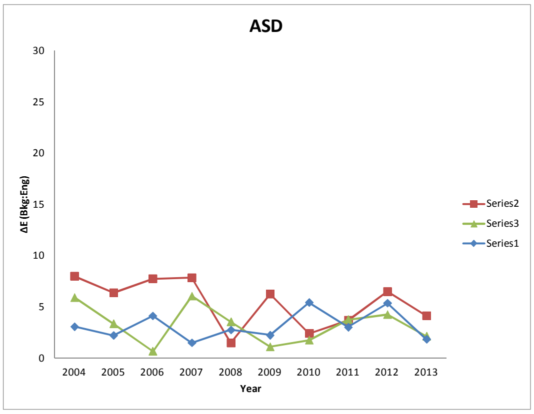


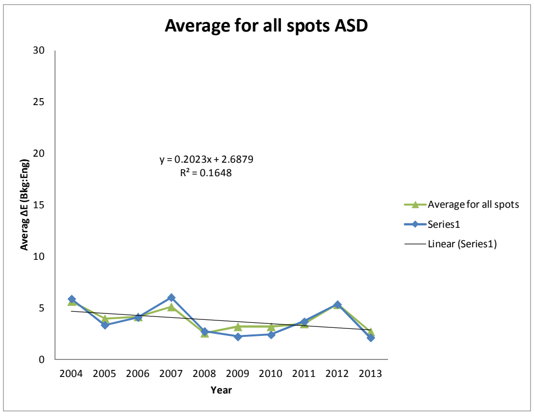


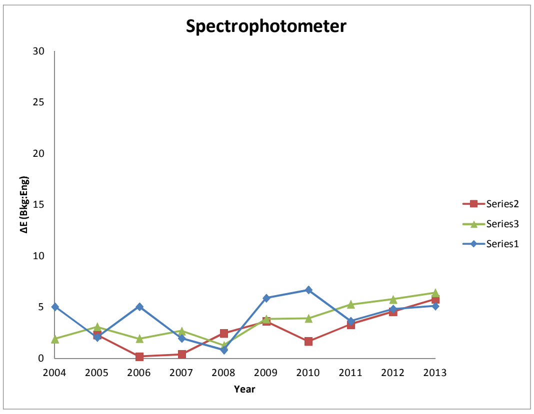




Site 8 King Bay South







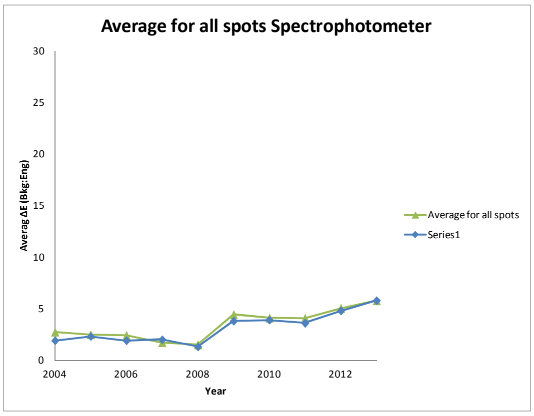


Figure 35: ASD reflectance spectrometer and colour measurements for each site, 2004-2013.

8. Conclusion of 2004-2013 study

The petroglyphs at 7 sites in the Burrup Peninsula were measured annually from 2004 to 2012. The same engravings and background rocks were measured *in situ*. Measurement of the annual colour changes utilised two spectrophotometer techniques, the Analytical Spectral Device (ASD) and the BYK colour spectrophotometer. An examination of the colour measurements as a function of time, as well as a comparison of the two measurement techniques, has been conducted.

The degree of variance within the measurements obtained using the different techniques is largely attributed to the instrument design and is a function of the ASD having a larger measurement window and exhibits less measurement variance while the BYK instrument has a smaller measurement window and therefore exhibits greater measurement variance. It also has a larger planar surface which is more susceptible to coarse grain surface roughness. It can be seen that some sites with rougher surfaces (e.g., 5 and 7) have greater variance with both instruments compared with sites with smoother surfaces (e.g., 6) so there is consistency between the instruments.

In a comparison of both the Northern and Southern sites, there is no specific trend observed. In considering the Northern control sites and Southern test sites, neither show a consistent trend in an increasing or decreasing direction, but rather a stable degree of colour difference between engravings and background.

A robust statiscal analysis of the ASD spectra was conducted for the first time and showed that none of the engravings or background showed systematic change through time.

9. References

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Appendix A Statistical Analyses of the Colour Spectra

The models for KM measurements are:

L* =

32.5897 + 1.8544 typee - 0.0088 BL + 0.8412 site1:spot1 - 1.1356 site2:spot1 - 0.8454 site4:spot1 + 1.4091 site5:spot1 + 7.2404 site6:spot1 - 3.2839 site7:spot1 + 0.2407 site8:spot1 - 0.7995 site1:spot2 - 2.94 site2:spot2 - 0.1867 site4:spot2 - 0.8154 site5:spot2 + 6.0087 site6:spot2 - 2.0135 site7:spot2 + 0.2684 site8:spot2 - 2.2728 site1:spot3 - 1.9294 site2:spot3 - 0.2726 site4:spot3 + 2.5164 site5:spot3 + 6.5082 site6:spot3 - 4.8493 site7:spot3 + 7.3502 site1:spot1:typee + 7.4851 site2:spot1:typee + 2.1525 site4:spot1:typee + 3.2365 site5:spot1:typee - 0.5179 site6:spot1:typee + 5.5494 site7:spot1:typee + 0.8457 site8:spot1:typee - 0.0638 site1:spot2:typee + 13.4698 site2:spot2:typee - 0.2725 site4:spot2:typee + 4.5048 site5:spot2:typee - 0.5028 site6:spot2:typee + 1.8822 site7:spot2:typee + 1.1819 site8:spot2:typee + 7.087 site1:spot3:typee + 10.2407 site2:spot3:typee + 2.345 site4:spot3:typee + 2.5702 site5:spot3:typee - 1.6006 site6:spot3:typee + 4.9272 site7:spot3:typee

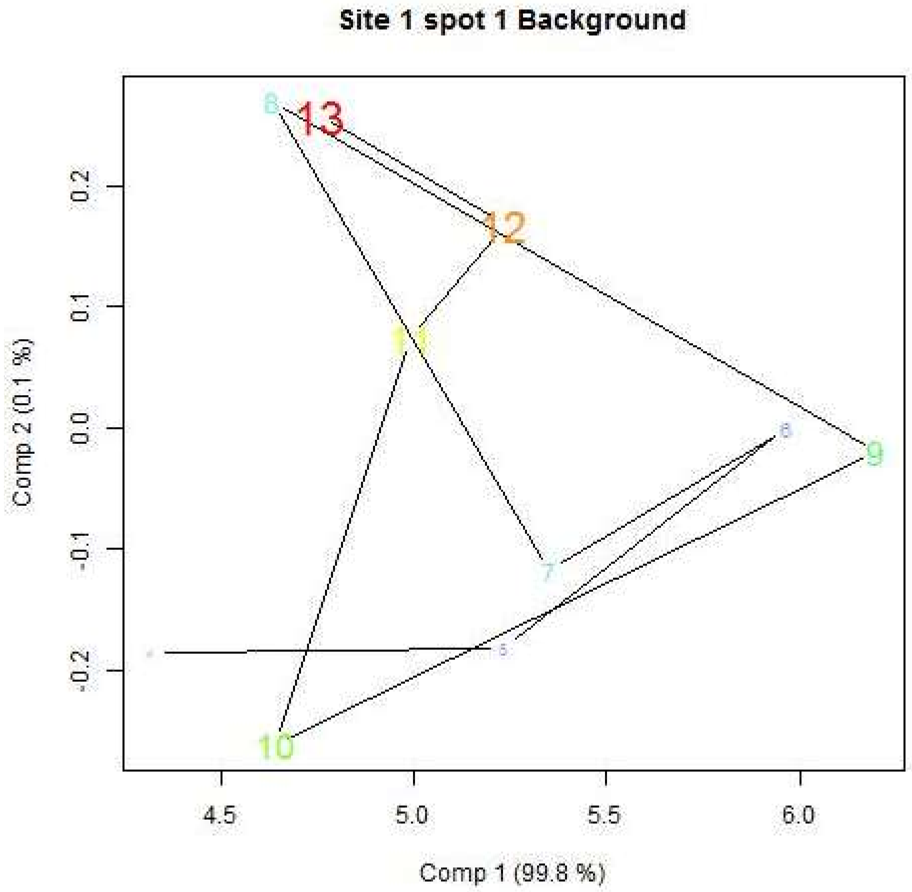
(where BL means the BYK measurement of L*, and terms involving typee are only added if the prediction is for an engraving; terms involving siteX are only added if the prediction is for site X; and terms involving spotY are only added if the prediction is for spot Y). Similarly,

a* =

2.0456 + 0.9627 typee + 0.8288 Ba + 8.7343 site1:spot1 + 6.7633 site2:spot1 + 13.6193 site4:spot1 + 17.4323 site5:spot1 + 12.5433 site6:spot1 + 13.0634 site7:spot1 + 18.7365 site8:spot1 + 8.2463 site1:spot2 + 7.8262 site2:spot2 + 12.4414 site4:spot2 + 9.5111 site5:spot2 + 3.159 site6:spot2 + 15.1255 site7:spot2 + 8.8064 site8:spot2 + 8.757 site1:spot3 + 7.7198 site2:spot3 + 9.3544 site4:spot3 + 11.5273 site5:spot3 + 8.217 site6:spot3 + 10.0399 site7:spot3 - 2.1327 site1:spot1:typee - 1.6425 site2:spot1:typee + 1.4085 site4:spot1:typee + 5.1063 site5:spot1:typee - 3.0632 site6:spot1:typee - 0.3253 site7:spot1:typee + 1.3757 site8:spot1:typee + 5.484 site1:spot2:typee - 0.9094 site2:spot2:typee + 0.2295 site4:spot2:typee + 3.4335 site5:spot2:typee - 1.4391 site6:spot2:typee - 1.5584 site7:spot2:typee + 1.3942 site8:spot2:typee + 3.2192 site1:spot3:typee - 2.2022 site2:spot3:typee + 1.0986 site4:spot3:typee + 4.6315 site5:spot3:typee - 2.449 site6:spot3:typee + 0.2277 site7:spot3:typee - 0.8263 site1:spot1:Ba - 0.6983 site2:spot1:Ba - 0.9514 site4:spot1:Ba - 1.2171 site5:spot1:Ba - 0.9342 site6:spot1:Ba - 0.9283 site7:spot1:Ba - 1.4849 site8:spot1:Ba - 0.8478 site1:spot2:Ba - 0.6801 site2:spot2:Ba - 0.8328 site4:spot2:Ba - 0.6175 site5:spot2:Ba - 0.2275 site6:spot2:Ba - 1.0133 site7:spot2:Ba - 0.7547 site8:spot2:Ba - 0.8903 site1:spot3:Ba - 0.5863 site2:spot3:Ba - 0.6294 site4:spot3:Ba - 0.8247 site5:spot3:Ba - 0.6094 site6:spot3:Ba - 0.768 site7:spot3:Ba

b* =

-8.5918 + 0.453 typee + 1.4137 Bb + 19.7657 site1:spot1 + 16.3202 site2:spot1 + 26.2775 site4:spot1 + 26.1983 site5:spot1 + 27.312 site6:spot1 + 24.5753 site7:spot1 + 38.9535 site8:spot1 + 19.8905 site1:spot2 + 23.1526 site2:spot2 + 22.9584 site4:spot2 + 19.9827 site5:spot2 + 4.4523 site6:spot2 + 25.1907 site7:spot2 + 17.2042 site8:spot2 + 19.3164 site1:spot3 + 23.9051 site2:spot3 + 20.3192 site4:spot3 + 21.3086 site5:spot3 + 24.1403 site6:spot3 + 21.4016 site7:spot3 + 7.1661 site1:spot1:typee + 4.1347 site2:spot1:typee + 4.625 site4:spot1:typee + 8.6356 site5:spot1:typee - 0.9679 site6:spot1:typee + 3.4649 site7:spot1:typee + 6.3 site8:spot1:typee + 6.953 site1:spot2:typee + 13.2094 site2:spot2:typee + 2.3973 site4:spot2:typee + 5.652 site5:spot2:typee - 0.4845 site6:spot2:typee + 1.1067 site7:spot2:typee + 1.9315 site8:spot2:typee + 8.329 site1:spot3:typee + 2.7233 site2:spot3:typee + 3.385 site4:spot3:typee + 7.4321 site5:spot3:typee - 1.0743 site6:spot3:typee + 2.3982 site7:spot3:typee - 1.5351 site1:spot1:Bb - 1.101 site2:spot1:Bb - 1.6306 site4:spot1:Bb - 1.6065 site5:spot1:Bb - 1.4799 site6:spot1:Bb - 1.4968 site7:spot1:Bb - 2.7502 site8:spot1:Bb - 1.4947 site1:spot2:Bb - 1.7826 site2:spot2:Bb - 1.353 site4:spot2:Bb - 1.1678 site5:spot2:Bb - 0.1691 site6:spot2:Bb - 1.5342 site7:spot2:Bb - 1.1322 site8:spot2:Bb - 1.4765 site1:spot3:Bb - 1.3405 site2:spot3:Bb - 1.17 site4:spot3:Bb - 1.2992 site5:spot3:Bb - 1.3405 site6:spot3:Bb - 1.3521 site7:spot3:Bb



[1] Site 1 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.00667	0.00667	0.0179	0.8972
I((4:13)^2)	1	0.59299	0.59299	1.5934	0.2473
Residuals	7	2.60503	0.37215		

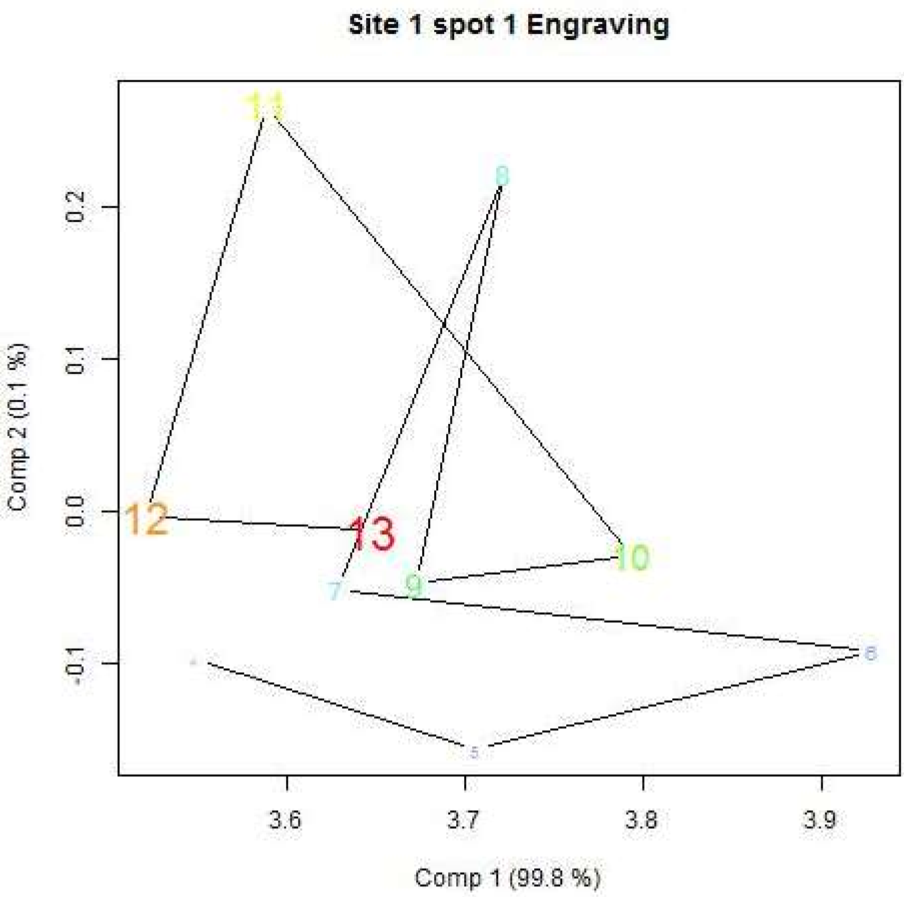
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

Res.Df RSS Df Sum of Sq F Pr(>F)

```
1      9 3.2047
2      7 2.6050  2   0.59966 0.8057 0.4843
[1] Site 1 spot 1 Background
Analysis of Variance Table

Response: coefs[i, ]
           Df   Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.112244 0.112244  3.7543 0.09387 .
I((4:13)^2)  1 0.001695 0.001695  0.0567 0.81862
Residuals    7 0.209284 0.029898
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.32322
2      7 0.20928  2   0.11394 1.9055 0.2184
```



[1] Site 1 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.00831	0.0083101	0.5798	0.4712
I((4:13)^2)	1	0.02253	0.0225303	1.5720	0.2502
Residuals	7	0.10032	0.0143321		

Analysis of Variance Table

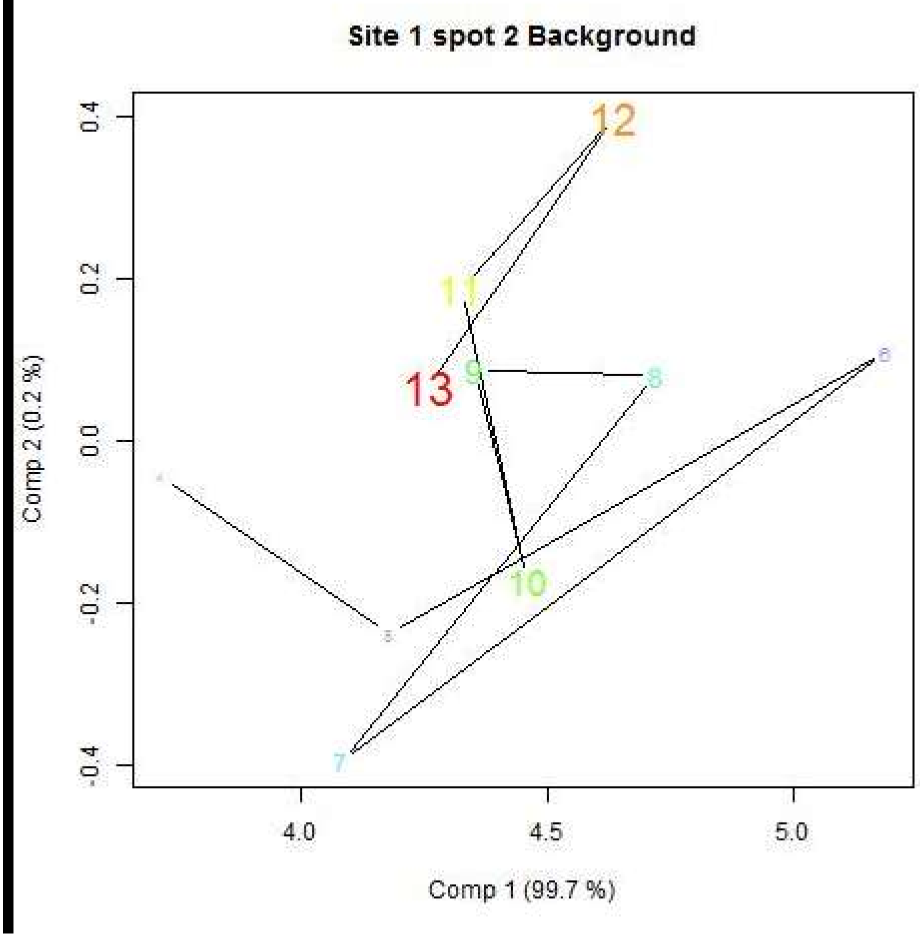
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.13117				
2	7	0.10032	2	0.03084	1.0759	0.3913

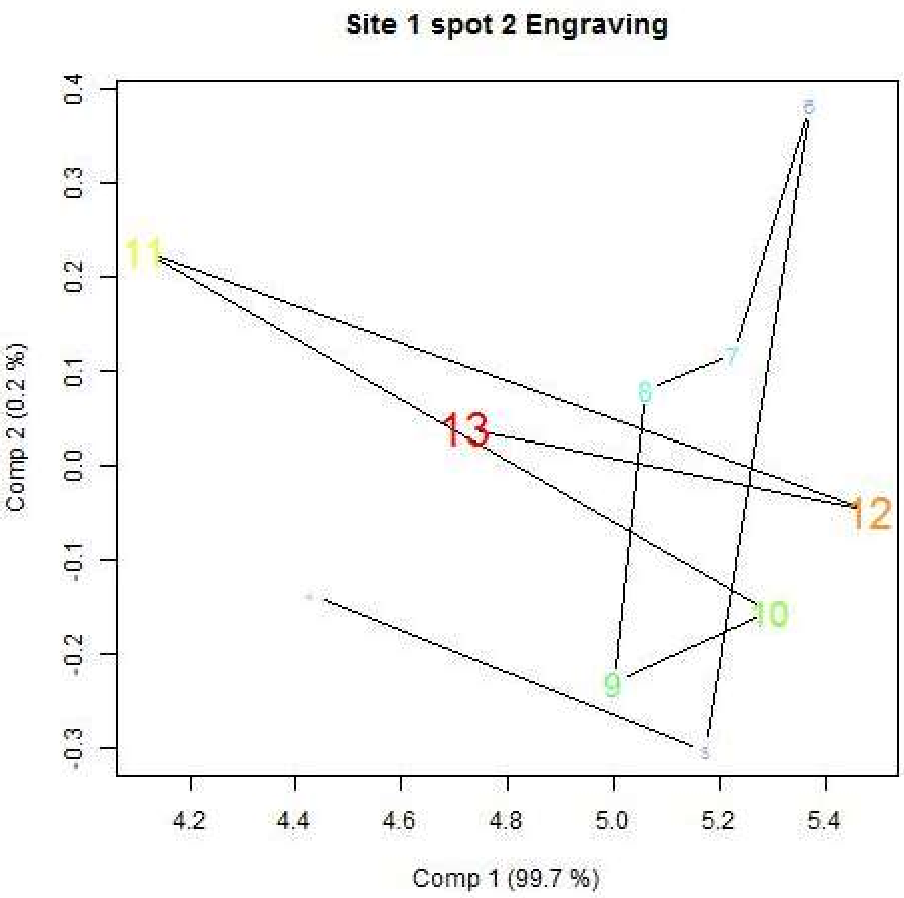
[1] Site 1 spot 1 Engraving

```
Analysis of Variance Table


Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.035762 0.035762  2.2001 0.1816
I((4:13)^2)  1 0.019756 0.019756  1.2154 0.3067
Residuals    7 0.113780 0.016254
Analysis of Variance Table


Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.16930
2      7 0.11378  2  0.055518 1.7078 0.2489
```




```
[1] Site 1 spot 2 Background
```

```
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.06269 0.06269  0.4017 0.5464
I((4:13)^2)  1 0.26799 0.26799  1.7171 0.2314
Residuals    7 1.09249 0.15607
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 1.4232
2      7 1.0925  2   0.33068 1.0594 0.3963
[1] Site 1 spot 2 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.12878 0.128775  2.7271 0.1426
I((4:13)^2)  1 0.01105 0.011052  0.2340 0.6433
Residuals    7 0.33055 0.047221
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.47037
2      7 0.33055  2   0.13983 1.4806 0.2909
```



[1] Site 1 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.00538 0.005376  0.0247 0.8795
I((4:13)^2)  1 0.19415 0.194149  0.8921 0.3764
Residuals    7 1.52342 0.217631
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 1.7229
2      7 1.5234  2   0.19953 0.4584   0.65
```

[1] Site 1 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

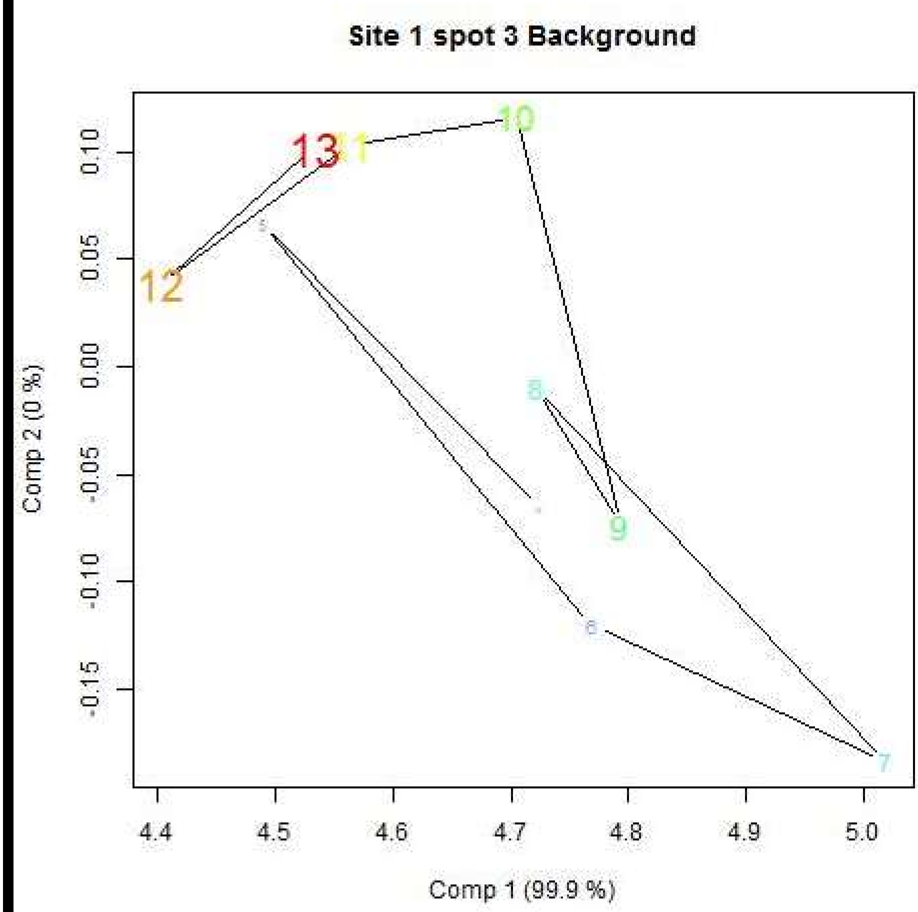
```
              Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)       1 0.00661 0.006606  0.1184 0.7408
I((4:13)^2)  1 0.01049 0.010490  0.1881 0.6776
Residuals    7 0.39040 0.055772
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

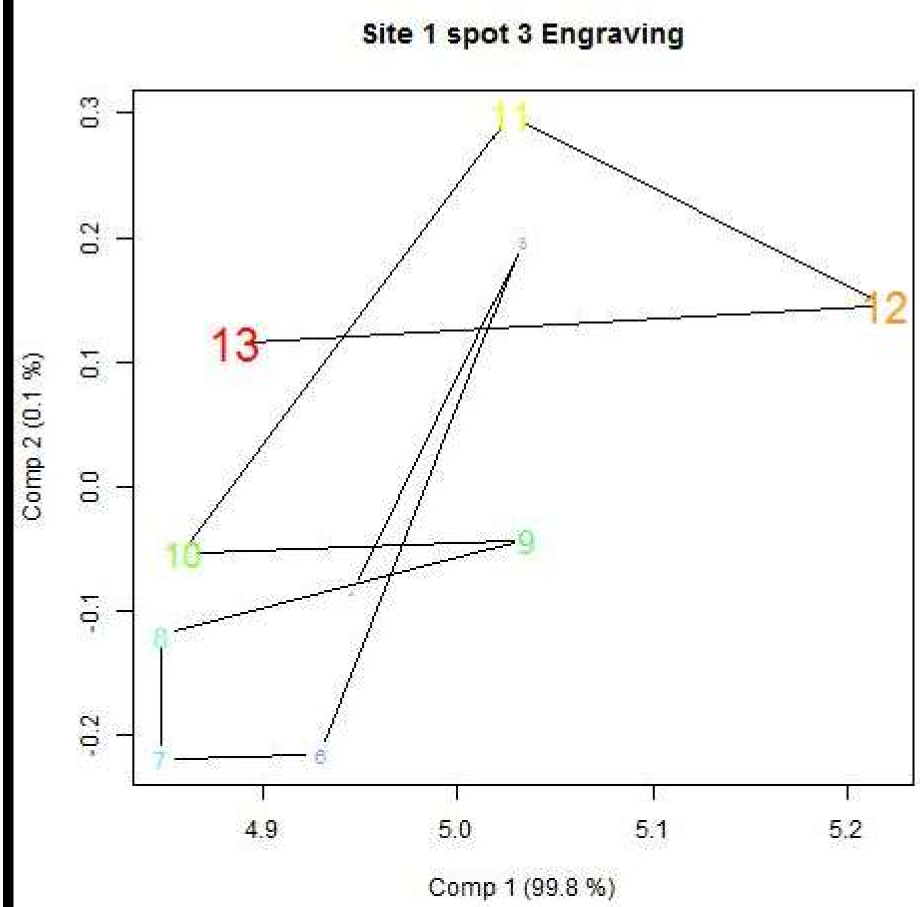
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 0.4075
2      7 0.3904  2  0.017096 0.1533 0.8607
```



[1] Site 1 spot 3 Background

```
Analysis of Variance Table

Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.053702 0.053702  2.4411 0.1622
I((4:13)^2)  1 0.078936 0.078936  3.5882 0.1000
Residuals    7 0.153991 0.021999
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.28663
2      7 0.15399  2   0.13264 3.0147 0.1137
[1] Site 1 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.032393 0.032393  3.8554 0.09035 .
I((4:13)^2)  1 0.007302 0.007302  0.8691 0.38224
Residuals    7 0.058813 0.008402
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df      RSS Df Sum of Sq      F Pr(>F)
1      9 0.098508
2      7 0.058813  2  0.039695 2.3622 0.1644
```



[1] Site 1 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
           Df   Sum Sq   Mean Sq F value Pr(>F)
I(4:13)     1 0.006465 0.0064654  0.4037 0.5454
I((4:13)^2)  1 0.005948 0.0059484  0.3714 0.5615
Residuals   7 0.112119 0.0160170
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
 Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.12453
2      7 0.11212  2  0.012414 0.3875 0.6924
```

[1] Site 1 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

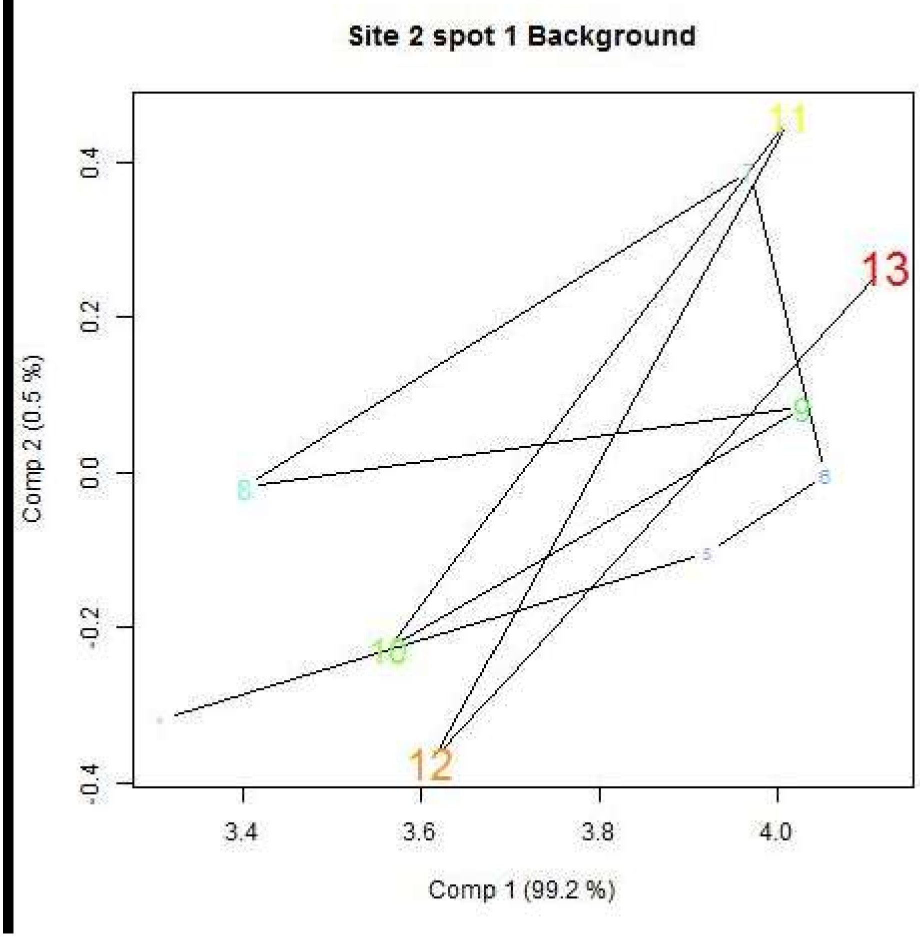
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.063595	0.063595	2.4671	0.1602
I((4:13)^2)	1	0.038304	0.038304	1.4860	0.2623
Residuals	7	0.180439	0.025777		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

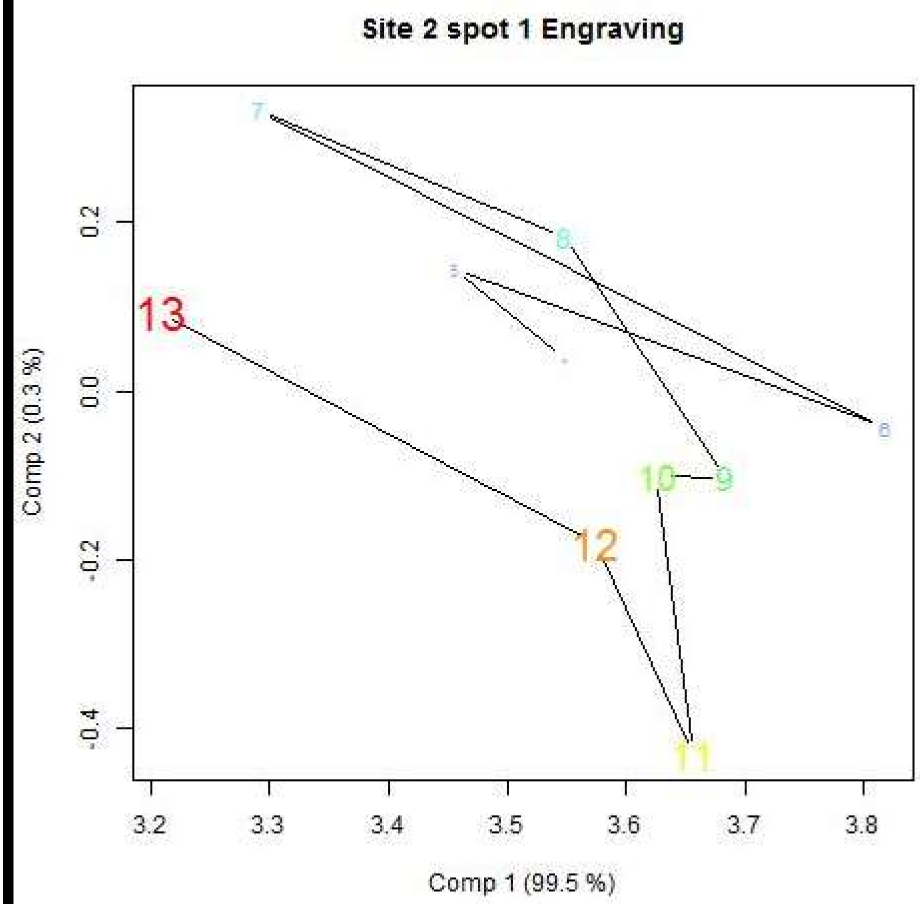
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.28234				
2	7	0.18044	2	0.1019	1.9765	0.2087



[1] Site 2 spot 1 Background

```
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.05819 0.058189  0.5498 0.4825
I((4:13)^2)  1 0.00432 0.004323  0.0408 0.8456
Residuals    7 0.74089 0.105841
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.80340
2      7 0.74089  2  0.062512 0.2953 0.7531
[1] Site 2 spot 1 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.04672 0.046716  0.5065 0.4997
I((4:13)^2)  1 0.04592 0.045917  0.4978 0.5032
Residuals    7 0.64563 0.092232
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.73826
2      7 0.64563  2  0.092633 0.5022 0.6255
```



[1] Site 2 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.010995	0.010995	0.3216	0.5884
I((4:13)^2)	1	0.049131	0.049131	1.4368	0.2697
Residuals	7	0.239365	0.034195		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.29949				
2	7	0.23936	2	0.060126	0.8792	0.4564

[1] Site 2 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

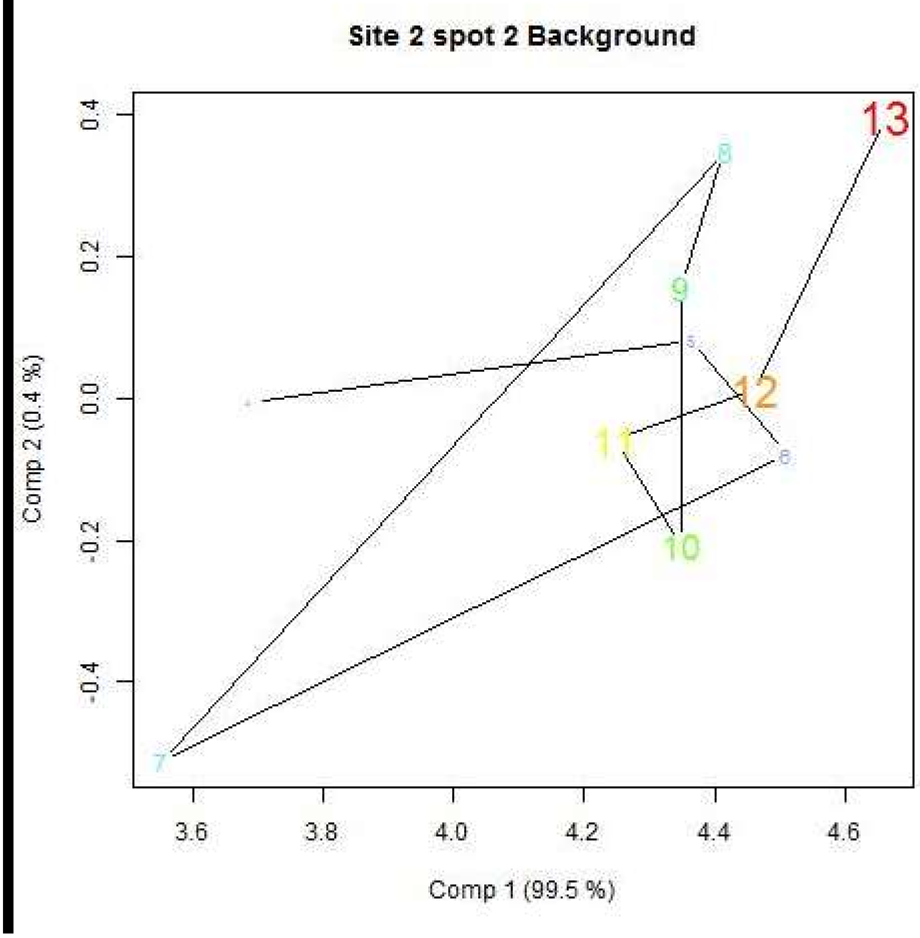
```
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.08544 0.085440  1.8057 0.2210
I((4:13)^2)  1 0.00022 0.000222  0.0047 0.9473
Residuals   7 0.33123 0.047318
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

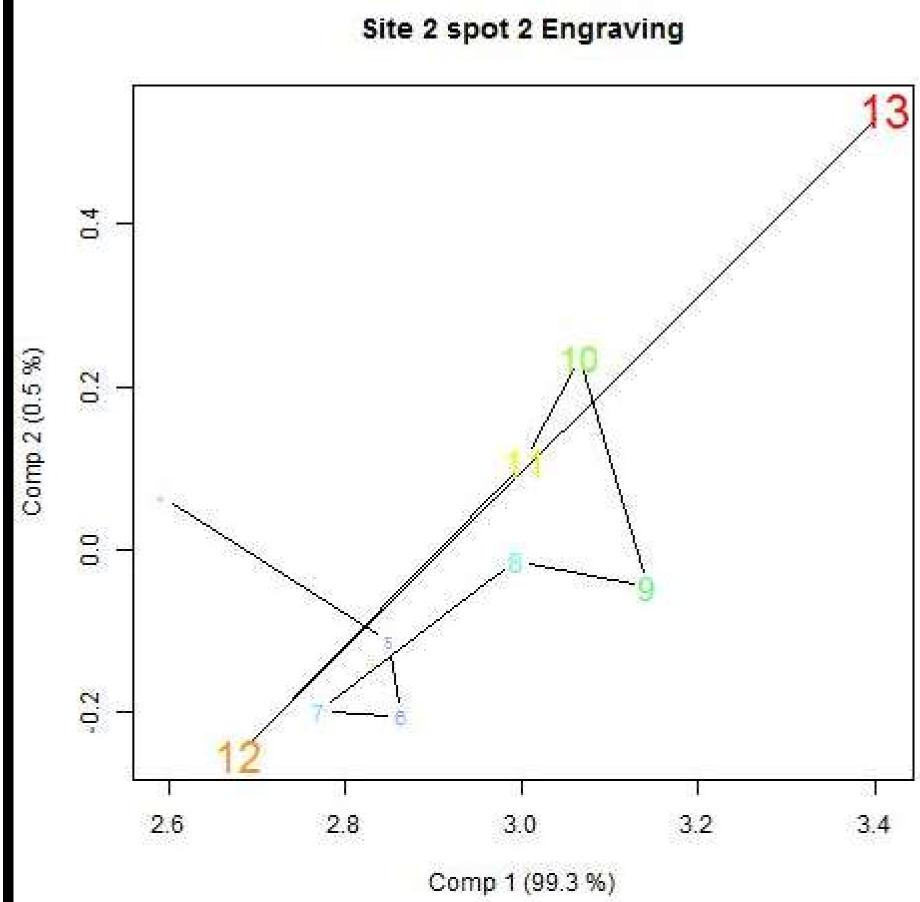
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.41689
2      7 0.33123  2  0.085662 0.9052 0.4471
```



[1] Site 2 spot 2 Background

```
Analysis of Variance Table

Response: coefs[i, ]
            Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.33274 0.33274  2.8601 0.1346
I((4:13)^2)  1 0.00037 0.00037  0.0032 0.9566
Residuals    7 0.81437 0.11634
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 1.14748
2      7 0.81437  2   0.33311 1.4316 0.3011
[1] Site 2 spot 2 Background
Analysis of Variance Table

Response: coefs[i, ]
            Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.04776 0.047759  0.6479 0.4474
I((4:13)^2)  1 0.05967 0.059674  0.8095 0.3982
Residuals    7 0.51603 0.073718
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.62346
2      7 0.51603  2   0.10743 0.7287 0.5159
```



[1] Site 2 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
            Df  Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.19013 0.190130  4.1265 0.08175 .
I((4:13)^2)  1 0.00539 0.005387  0.1169 0.74245
Residuals    7 0.32253 0.046076
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.51805
```

2   7 0.32253 2   0.19552 2.1217 0.1904

[1] Site 2 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13)   1 0.11395 0.113954 2.3929 0.1658

I((4:13)^2) 1 0.07383 0.073830 1.5504 0.2531

Residuals   7 0.33335 0.047621

Analysis of Variance Table

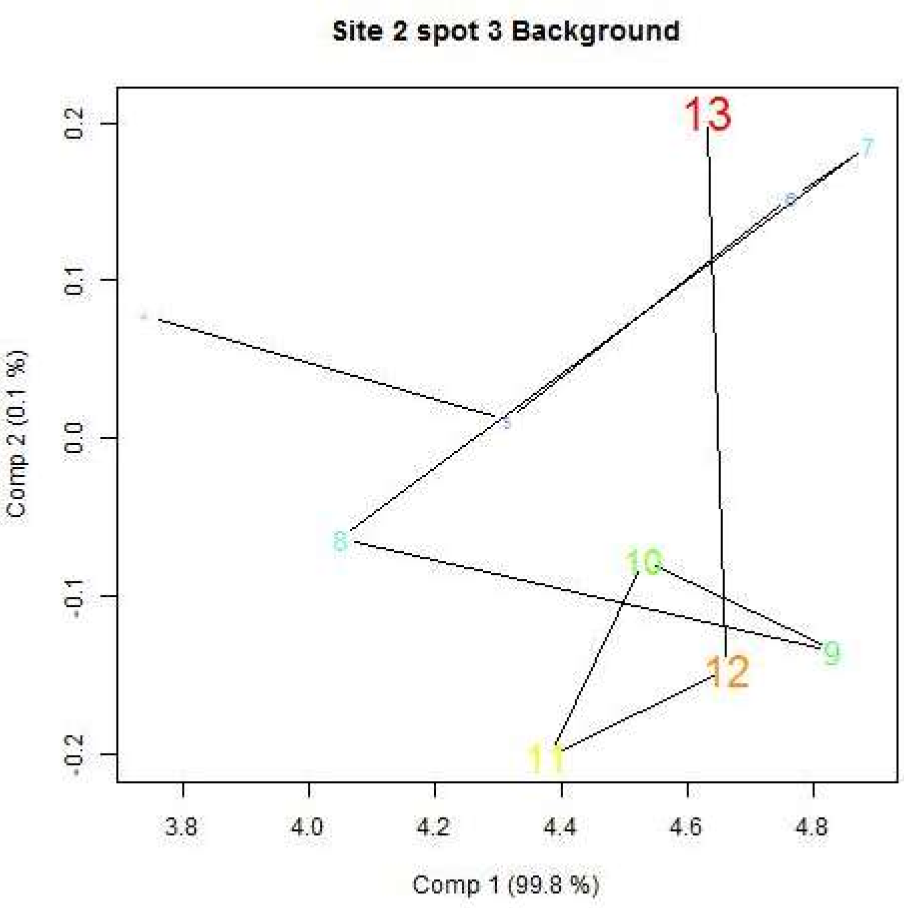
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

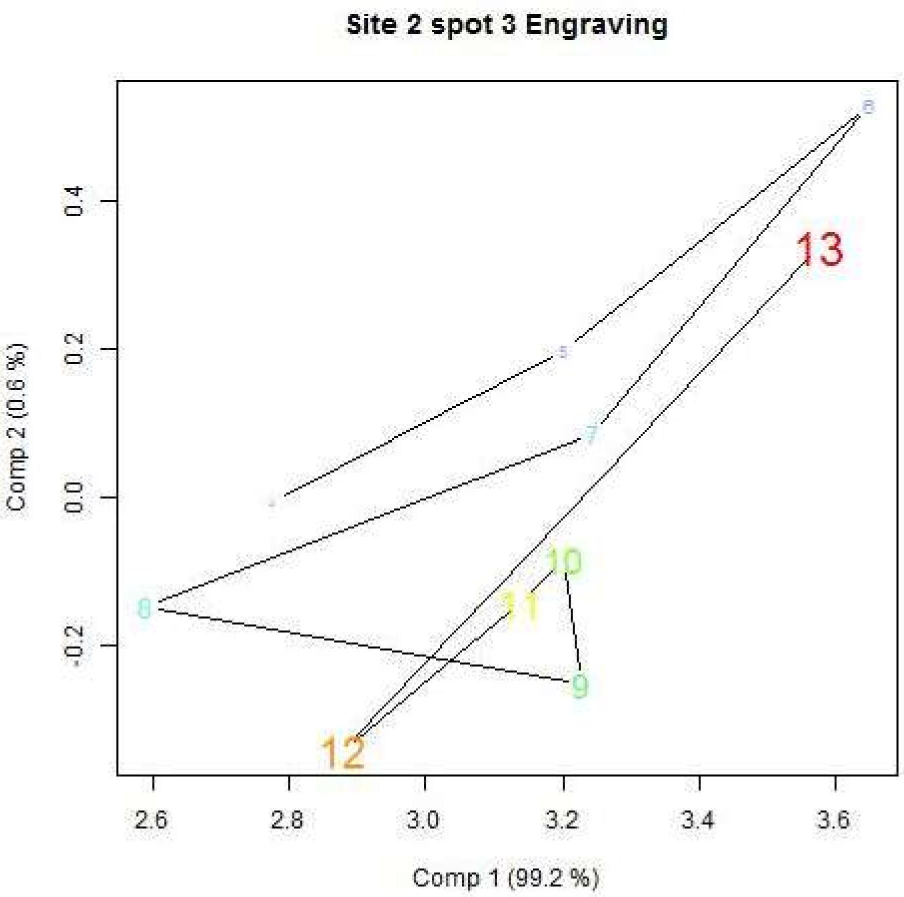
Res.Df   RSS Df Sum of Sq   F Pr(>F)

1   9 0.52113

2   7 0.33335 2   0.18778 1.9717 0.2093



```
[1] Site 2 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)     1 0.20569 0.20569  1.7430 0.2283
I((4:13)^2)  1 0.17125 0.17125  1.4512 0.2675
Residuals    7 0.82604 0.11801
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 1.20298
2      7 0.82604  2   0.37694 1.5971 0.2683
[1] Site 2 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.020209 0.020209  0.9539 0.3613
I((4:13)^2)  1 0.028765 0.028765  1.3578 0.2821
Residuals    7 0.148298 0.021185
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.19727
2      7 0.14830  2  0.048974 1.1558 0.3683
```




```
[1] Site 2 spot 3 Engraving
Analysis of Variance Table


Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.02542 0.025417  0.1876  0.678
I((4:13)^2)  1 0.00580 0.005799  0.0428  0.842
Residuals    7 0.94848 0.135497
Analysis of Variance Table


Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.97970
2      7 0.94848  2  0.031216 0.1152 0.8929
[1] Site 2 spot 3 Engraving
```

Analysis of Variance Table

Response: coefs[i,]

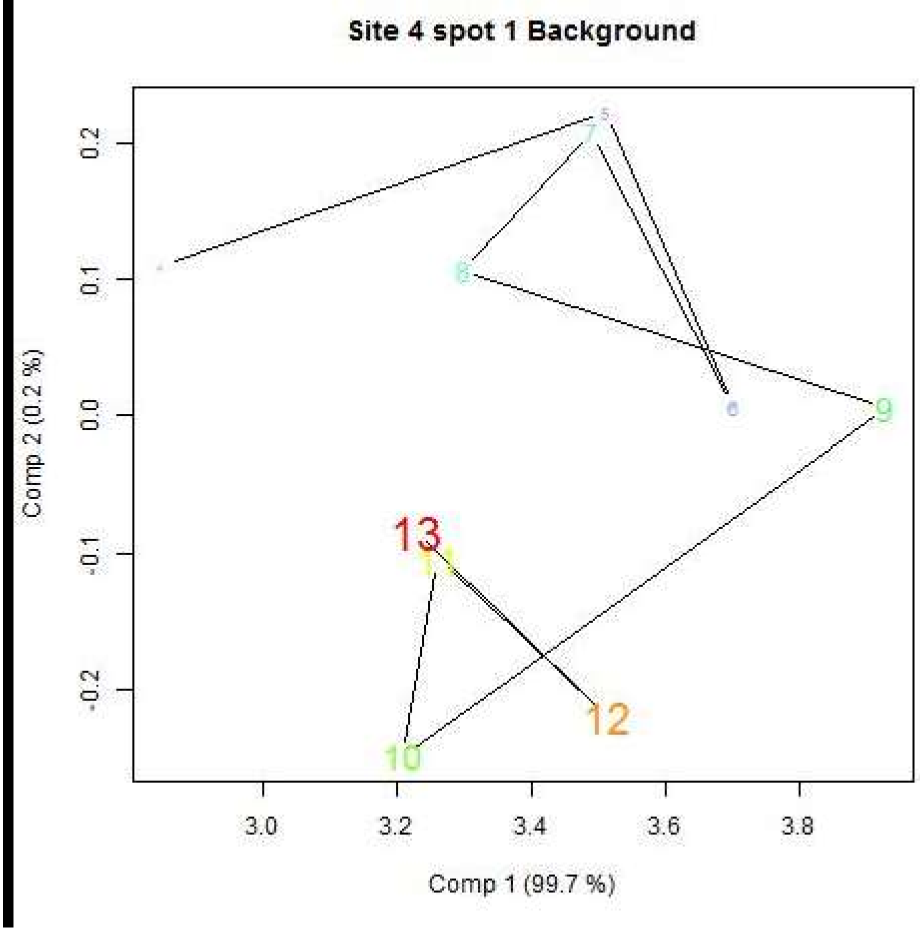
```
            Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.06572 0.065718  0.8579 0.3852
I((4:13)^2)  1 0.06428 0.064279  0.8391 0.3901
Residuals    7 0.53625 0.076607
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

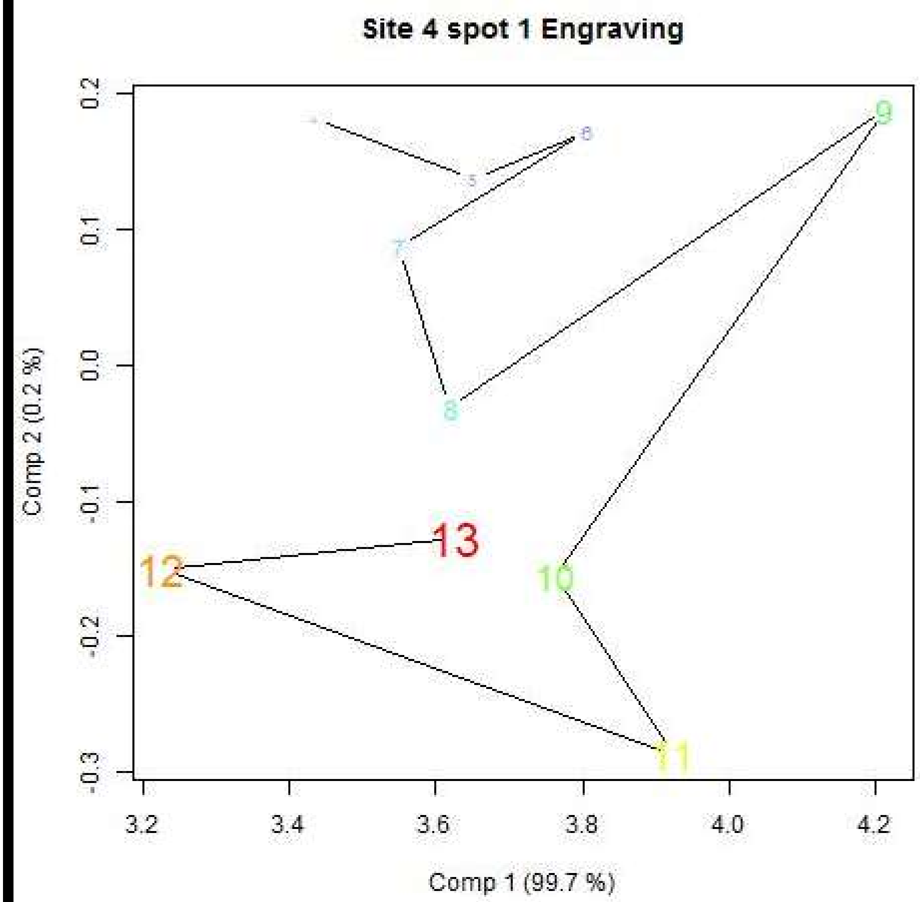
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.66625
2      7 0.53625  2      0.13 0.8485 0.4678
```



[1] Site 4 spot 1 Background

```
Analysis of Variance Table

Response: coefs[i, ]

          Df  Sum Sq Mean Sq F value Pr(>F)

I(4:13)      1 0.00329 0.00329  0.0402 0.8469

I((4:13)^2)  1 0.22475 0.22475  2.7442 0.1416

Residuals    7 0.57330 0.08190

Analysis of Variance Table


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F Pr(>F)

1      9 0.80134

2      7 0.57330  2   0.22804 1.3922 0.3097

[1] Site 4 spot 1 Background

Analysis of Variance Table


Response: coefs[i, ]

        Df  Sum Sq  Mean Sq F value   Pr(>F)

I(4:13)    1 0.14390 0.143898  11.267 0.009981 **

Residuals  8 0.10217 0.012772

Response: coefs[i, ]

          Df   Sum Sq  Mean Sq F value  Pr(>F)

I(4:13)      1 0.143898 0.143898  9.8619 0.01637 * downward trend in PC2

I((4:13)^2)  1 0.000033 0.000033  0.0023 0.96330

Residuals    7 0.102139 0.014591


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F  Pr(>F)

1      9 0.24607

2      7 0.10214  2   0.14393 4.9321 0.04608 *
```



[1] Site 4 spot 1 Engraving
Analysis of Variance Table
Response: coefs[i,]

```
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.00102 0.001019  0.0150 0.9060
I((4:13)^2)  1 0.18006 0.180055  2.6504 0.1475
Residuals    7 0.47555 0.067935
```

Analysis of Variance Table
Model 1: coefs[i,] ~ 1
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.65662
2      7 0.47555  2   0.18107 1.3327 0.3233
```

[1] Site 4 spot 1 Engraving
Analysis of Variance Table

Response: coefs[i,]

```
        Df   Sum Sq  Mean Sq F value   Pr(>F)
I(4:13)    1 0.174724 0.174724  14.628 0.005056 **
Residuals  8 0.095557 0.011945
```

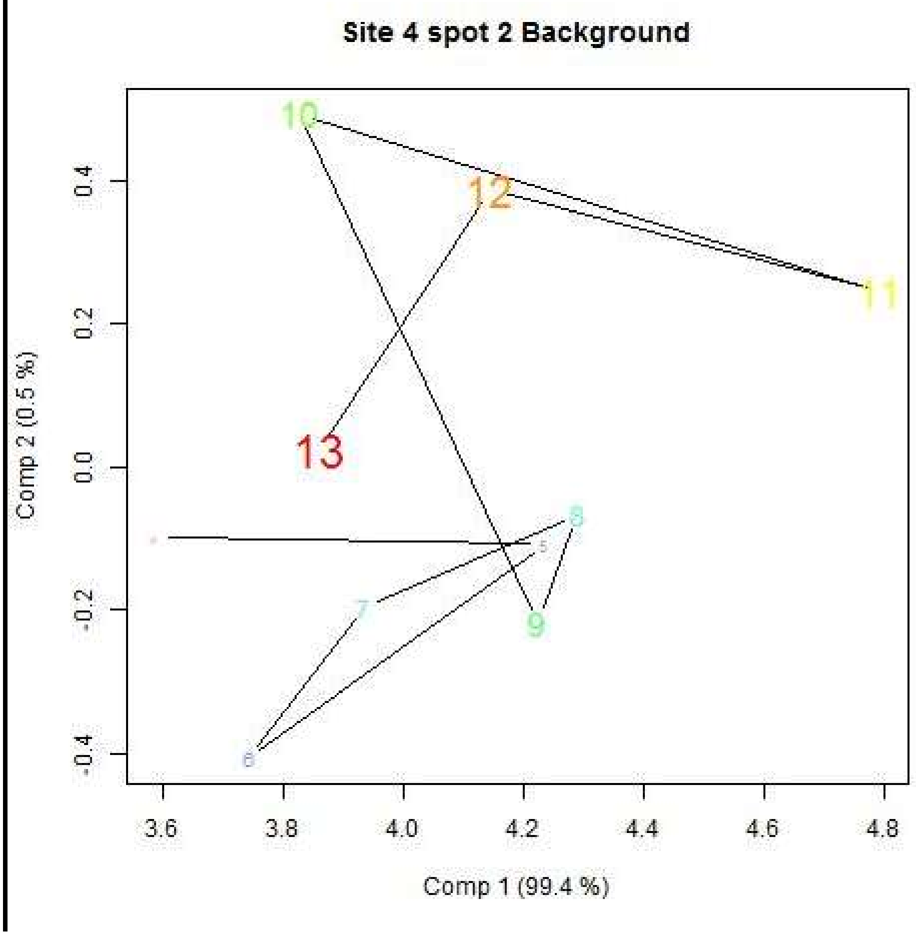
Response: coefs[i,]

```
           Df   Sum Sq  Mean Sq F value   Pr(>F)
I(4:13)      1 0.174724 0.174724 12.7995 0.009005 ** downward trend in PC2
I((4:13)^2)  1 0.000001 0.000001  0.0001 0.994514
Residuals    7 0.095556 0.013651
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
 Res.Df      RSS Df Sum of Sq      F  Pr(>F)
1      9 0.270282
2      7 0.095556  2   0.17472 6.3998 0.02628 *
```



[1] Site 4 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

```
           Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.13666 0.13666  1.1874 0.3119
I((4:13)^2)  1 0.14877 0.14877  1.2926 0.2930
Residuals    7 0.80563 0.11509
```

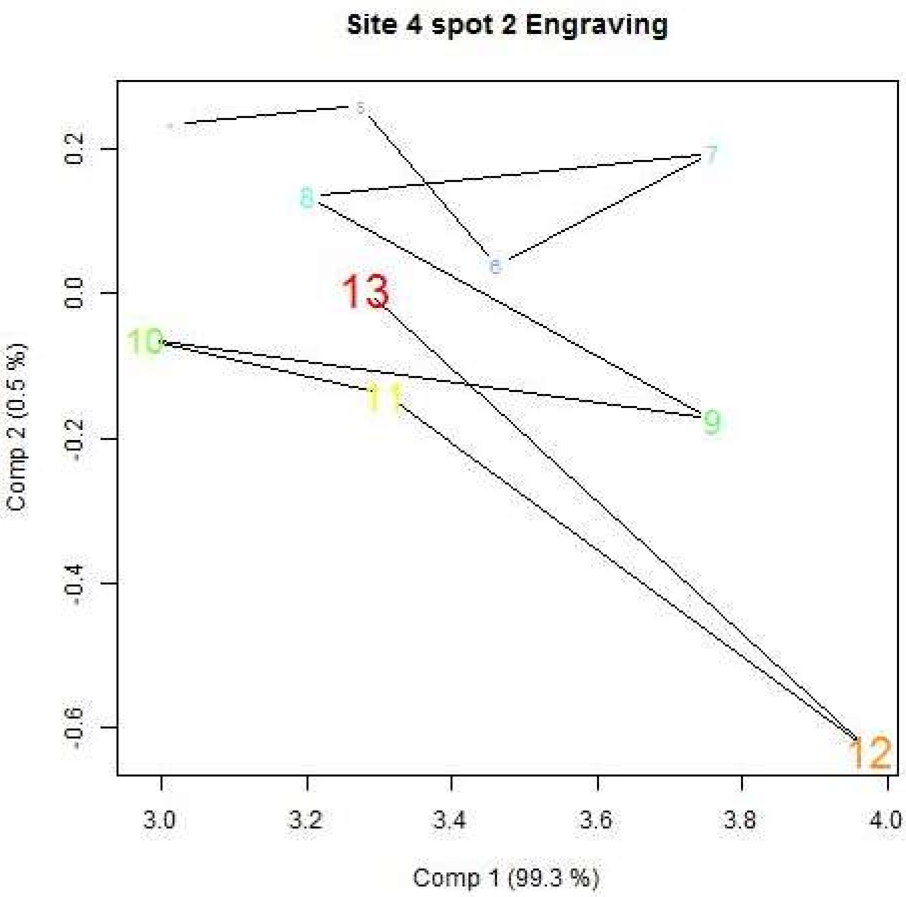
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

 Res.Df   RSS Df Sum of Sq   F Pr(>F)

```
1     9 1.09106
2     7 0.80563  2   0.28543 1.24 0.3459
[1] Site 4 spot 2 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.28780 0.287802  4.5775 0.06968 .
I((4:13)^2)  1 0.00198 0.001983  0.0315 0.86408
Residuals    7 0.44011 0.062873
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1     9 0.72989
2     7 0.44011  2   0.28979 2.3045 0.1702
```




```
[1] Site 4 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i, ]

          Df  Sum Sq  Mean Sq F value Pr(>F)

I(4:13)      1 0.06842 0.068421  0.5429 0.4852

I((4:13)^2)  1 0.04986 0.049865  0.3956 0.5493

Residuals    7 0.88224 0.126034

Analysis of Variance Table

Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F Pr(>F)

1      9 1.00053

2      7 0.88224  2   0.11829 0.4693 0.6438

[1] Site 4 spot 2 Engraving

Analysis of Variance Table
```

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.32245 0.32245 8.2856 0.02056 *

Residuals 8 0.31134 0.03892

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.32245 0.32245 7.3071 0.0305 * downward trend in PC2

I((4:13)^2) 1 0.00244 0.00244 0.0553 0.8209

Residuals 7 0.30890 0.04413

Analysis of Variance Table

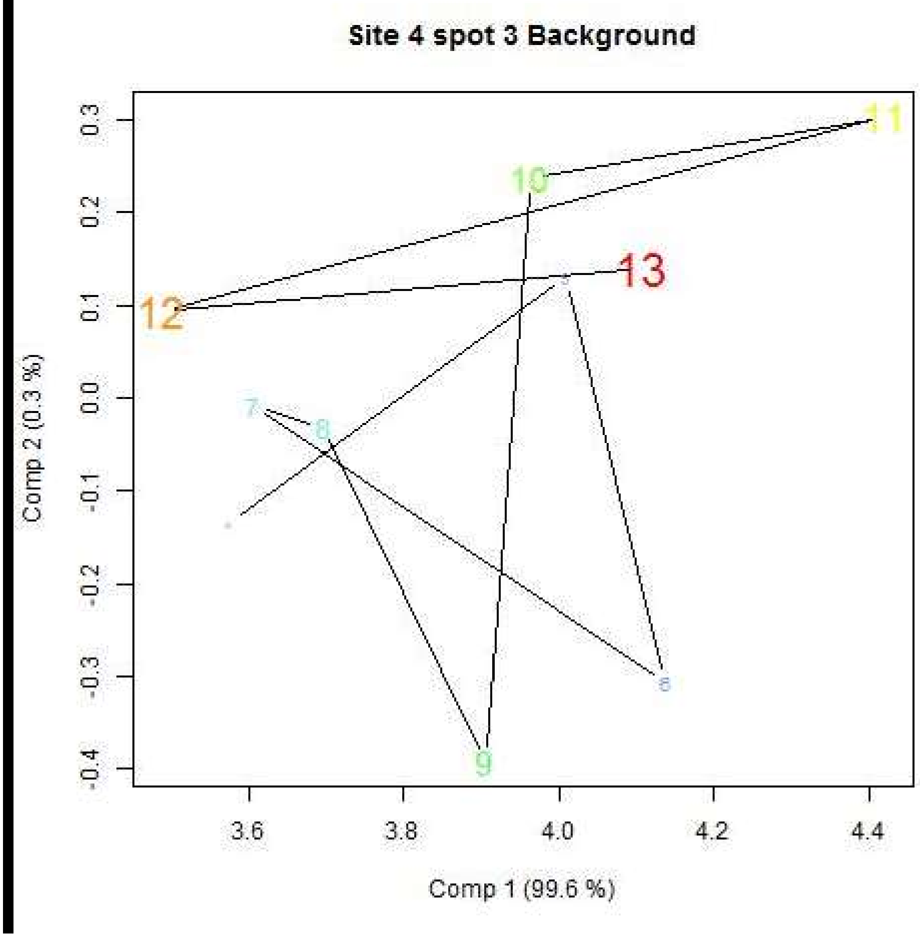
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

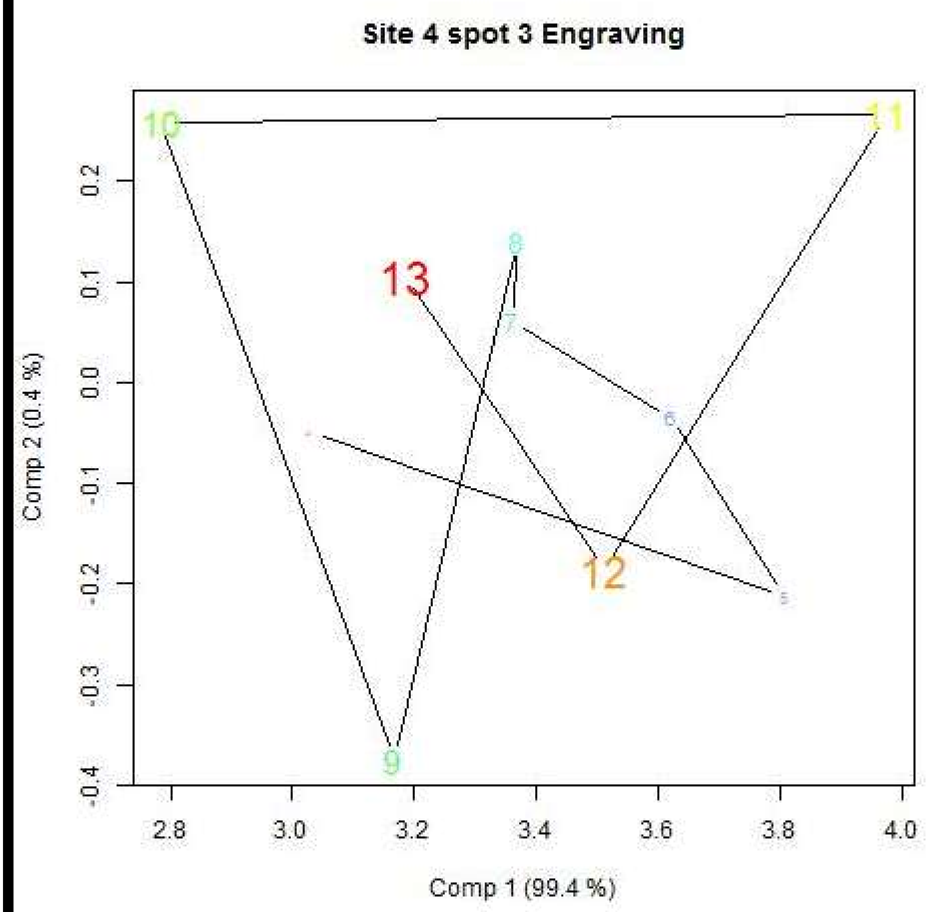
Res.Df RSS Df Sum of Sq F Pr(>F)

1 9 0.63378

2 7 0.30890 2 0.32489 3.6812 0.08083 .



```
[1] Site 4 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.04458 0.044577  0.4208 0.5372
I((4:13)^2)  1 0.00256 0.002563  0.0242 0.8808
Residuals   7 0.74146 0.105923
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.78860
2      7 0.74146  2  0.047141 0.2225 0.8059
[1] Site 4 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.09626 0.096256  1.9491 0.2054
I((4:13)^2)  1 0.01677 0.016772  0.3396 0.5783
Residuals   7 0.34570 0.049385
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.45872
2      7 0.34570  2   0.11303 1.1443 0.3715
```



[1] Site 4 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.00186 0.001860  0.0112 0.9188
I((4:13)^2)  1 0.00048 0.000481  0.0029 0.9586
Residuals   7 1.16629 0.166613
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df    RSS Df Sum of Sq     F Pr(>F)
1      9 1.1686
2      7 1.1663  2  0.002341 0.007  0.993
```

[1] Site 4 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

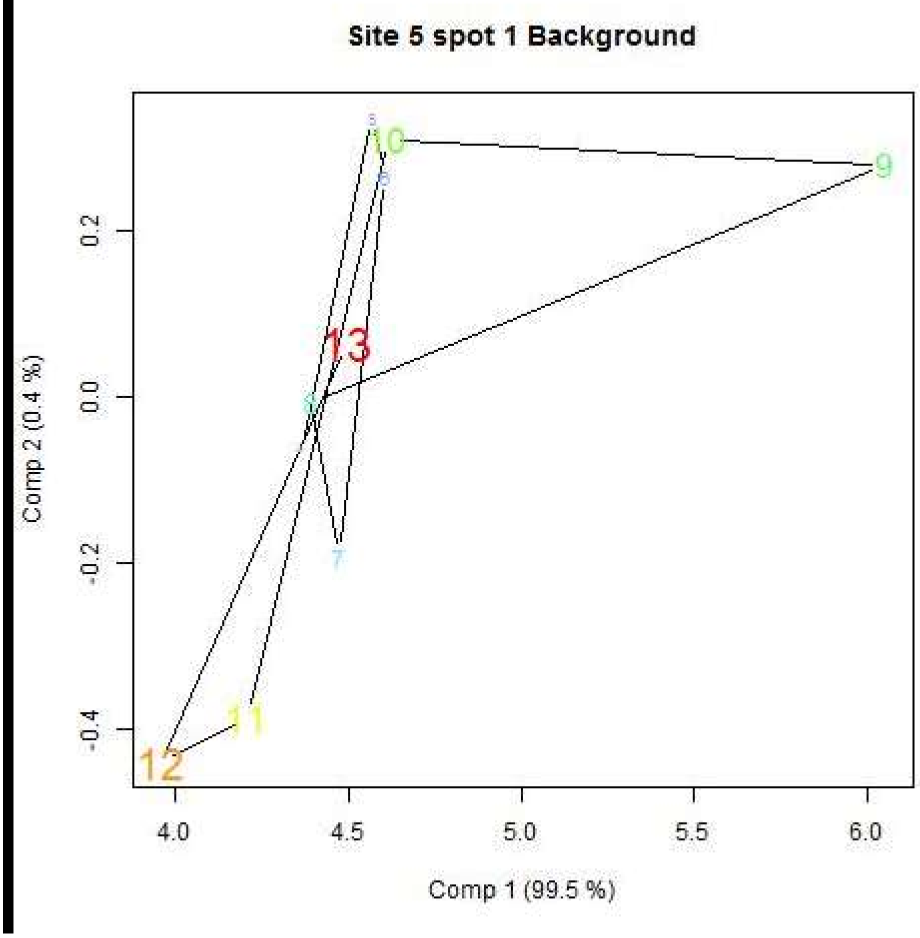
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.03005	0.030053	0.5833	0.4700
I((4:13)^2)	1	0.00379	0.003788	0.0735	0.7941
Residuals	7	0.36064	0.051520		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

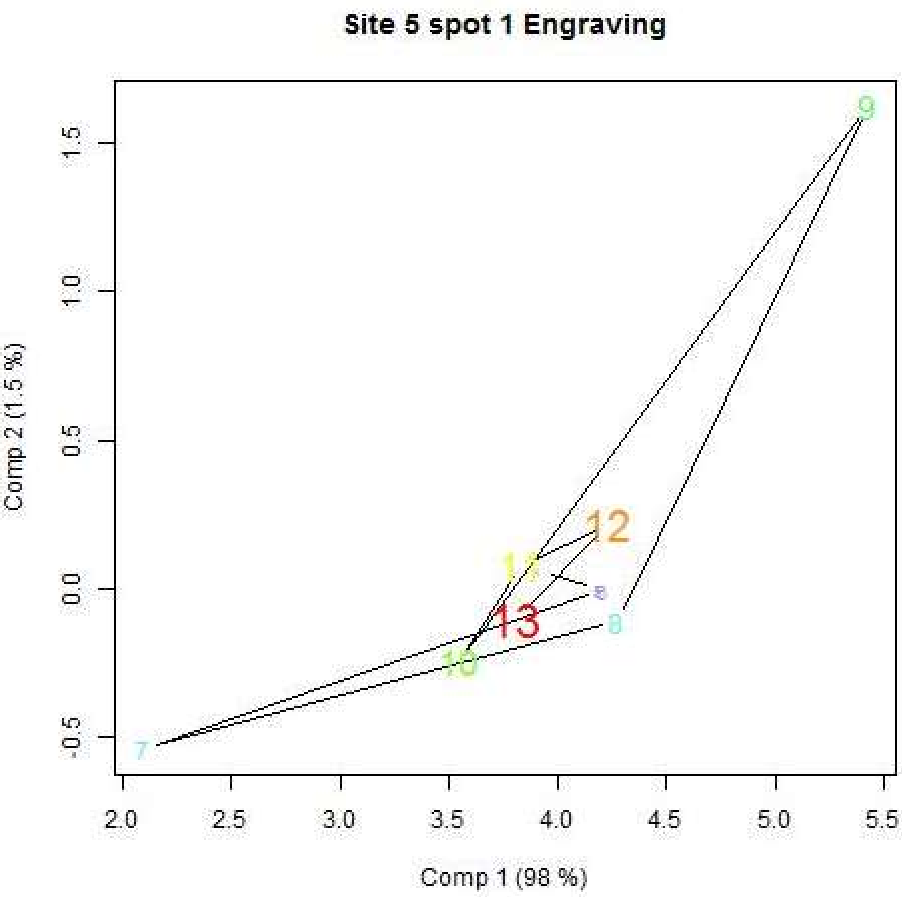
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.39448				
2	7	0.36064	2	0.033841	0.3284	0.7306



[1] Site 5 spot 1 Background

```
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.02786 0.02786  0.0837 0.7807
I((4:13)^2)  1 0.44102 0.44102  1.3252 0.2875
Residuals    7 2.32952 0.33279
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 2.7984
2      7 2.3295  2   0.46889 0.7045 0.5263
[1] Site 5 spot 1 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.10029 0.100287  1.1278 0.3235
I((4:13)^2)  1 0.01750 0.017501  0.1968 0.6707
Residuals    7 0.62247 0.088924
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.74026
2      7 0.62247  2   0.11779 0.6623 0.5452
```



[1] Site 5 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.0298	0.02981	0.0342	0.8584
I((4:13)^2)	1	0.0026	0.00264	0.0030	0.9576
Residuals	7	6.0938	0.87055		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	6.1263				
2	7	6.0938	2	0.032452	0.0186	0.9816

[1] Site 5 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

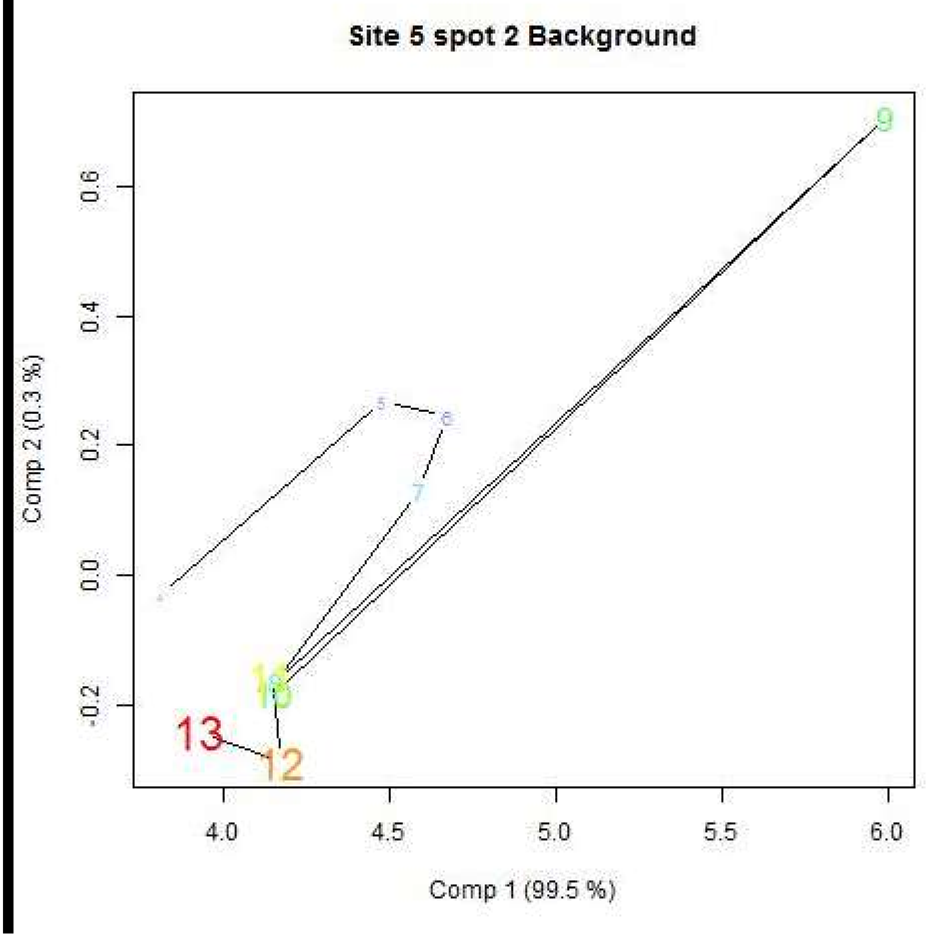
```
            Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.02905 0.02905  0.0716 0.7967
I((4:13)^2)  1 0.09673 0.09673  0.2385 0.6402
Residuals    7 2.83918 0.40560
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

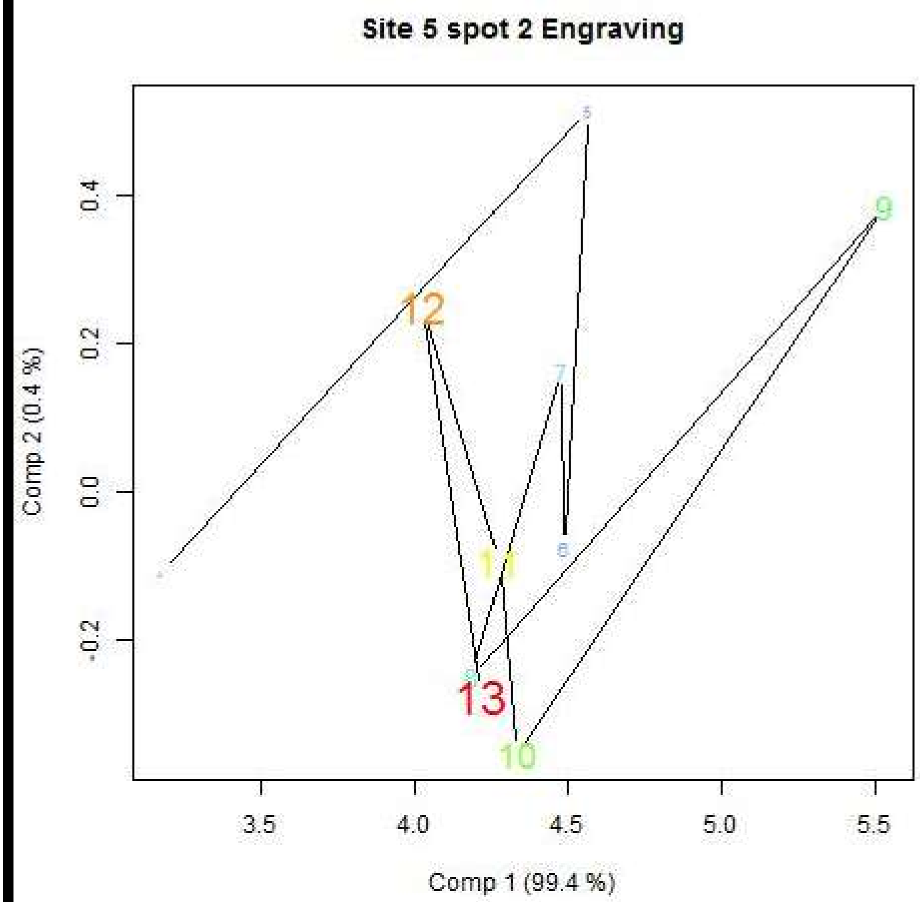
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 2.9650
2      7 2.8392  2   0.12578 0.1551 0.8592
```



[1] Site 5 spot 2 Background

```
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.03078 0.03078  0.0918 0.7707
I((4:13)^2)  1 1.07017 1.07017  3.1935 0.1171
Residuals    7 2.34573 0.33510
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 3.4467
2      7 2.3457  2    1.1009 1.6427 0.2601
[1] Site 5 spot 2 Background
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.18459 0.184595  2.2797 0.1748
I((4:13)^2)  1 0.10802 0.108016  1.3340 0.2860
Residuals    7 0.56682 0.080974
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.85943
2      7 0.56682  2   0.29261 1.8068  0.233
```



[1] Site 5 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
           Df  Sum Sq Mean Sq F value  Pr(>F)
I(4:13)      1 0.09308 0.09308  0.3774 0.55845
I((4:13)^2)  1 1.19042 1.19042  4.8260 0.06403 .
Residuals    7 1.72667 0.24667
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 3.0102
```

2   7 1.7267 2   1.2835 2.6017 0.1429

[1] Site 5 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

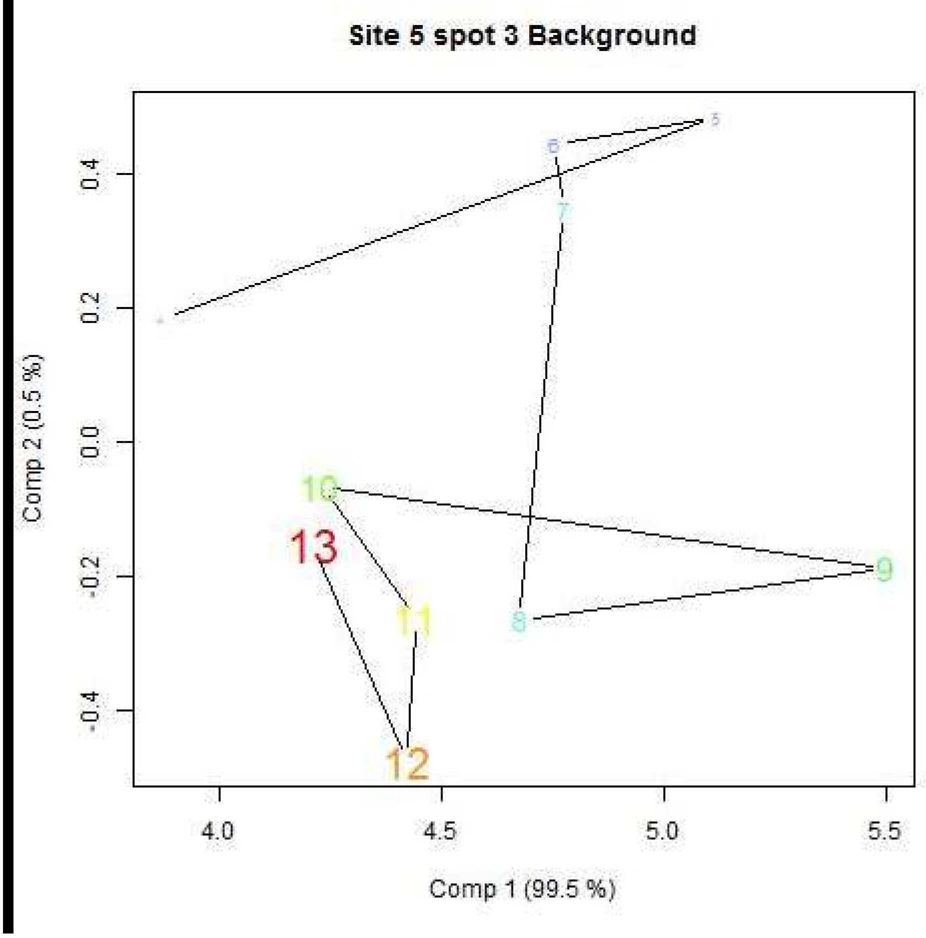
```
            Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.05771 0.057712  0.5542 0.4808
I((4:13)^2)  1 0.00247 0.002470  0.0237 0.8820
Residuals    7 0.72897 0.104138
```

Analysis of Variance Table

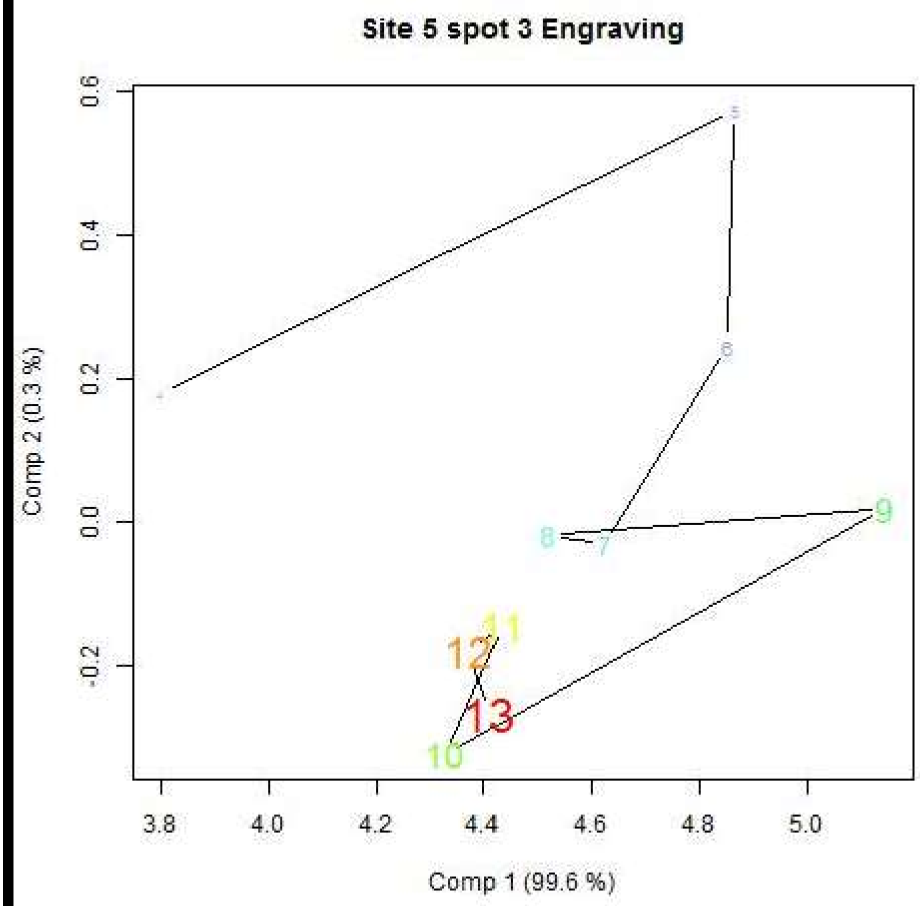
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq     F Pr(>F)
1      9 0.78915
2      7 0.72897  2  0.060182 0.289 0.7576
```



```
[1] Site 5 spot 3 Background

Analysis of Variance Table

Response: coefs[i, ]

           Df  Sum Sq Mean Sq F value Pr(>F)

I(4:13)      1 0.05266 0.05266  0.2824 0.6116

I((4:13)^2)  1 0.66009 0.66009  3.5397 0.1020

Residuals    7 1.30539 0.18648

Analysis of Variance Table

Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df    RSS Df Sum of Sq     F Pr(>F)

1      9 2.0181

2      7 1.3054  2   0.71276 1.911 0.2176

[1] Site 5 spot 3 Background

Analysis of Variance Table


Response: coefs[i, ]

         Df  Sum Sq Mean Sq F value   Pr(>F)

I(4:13)    1 0.62847 0.62847  13.208 0.006643 **

Residuals  8 0.38065 0.04758

Response: coefs[i, ]

           Df  Sum Sq Mean Sq F value  Pr(>F)

I(4:13)      1 0.62847 0.62847 11.7900 0.01093 * downward trend in PC2

I((4:13)^2)  1 0.00751 0.00751  0.1409 0.71846

Residuals    7 0.37313 0.05330

Analysis of Variance Table


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F  Pr(>F)

1      9 1.00911

2      7 0.37313  2   0.63598 5.9655 0.03074 *
```



[1] Site 5 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.00027	0.00027	0.0022	0.9639
I((4:13)^2)	1	0.37700	0.37700	3.1270	0.1203
Residuals	7	0.84394	0.12056		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	1.22121				
2	7	0.84394	2	0.37727	1.5646	0.2744

[1] Site 5 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.44037 0.44037 16.794 0.003447 **

Residuals 8 0.20978 0.02622

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.44037 0.44037 15.5221 0.005605 ** downward trend in PC2

I((4:13)^2) 1 0.01118 0.01118 0.3941 0.550052

Residuals 7 0.19859 0.02837

Analysis of Variance Table

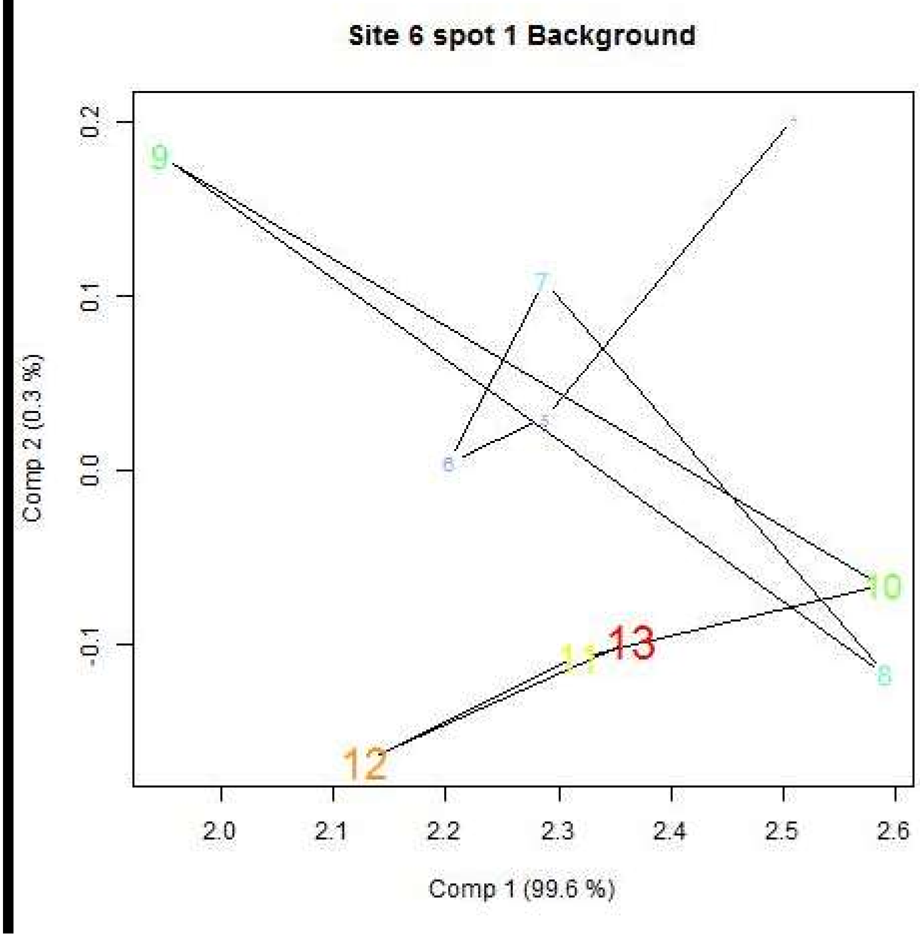
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

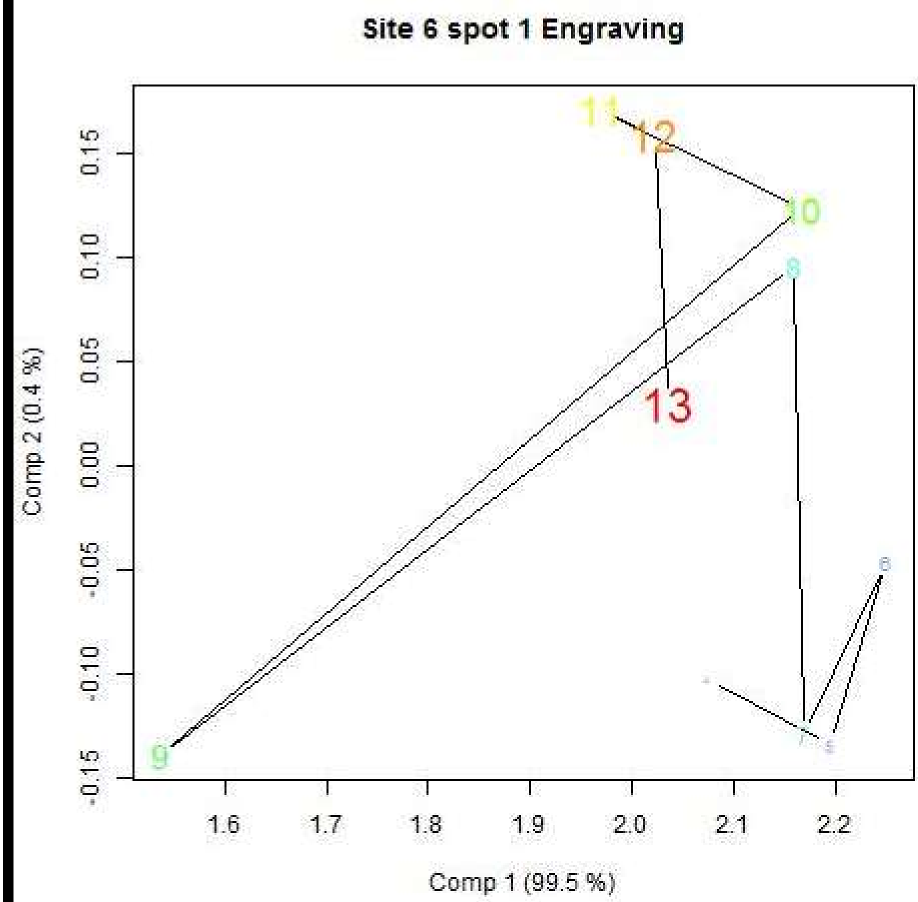
Res.Df RSS Df Sum of Sq F Pr(>F)

1 9 0.65015

2 7 0.19859 2 0.45155 7.9581 0.01575 *



```
[1] Site 6 spot 1 Background

Analysis of Variance Table

Response: coefs[i, ]

           Df  Sum Sq  Mean Sq F value Pr(>F)

I(4:13)      1 0.00749 0.007494  0.1452 0.7145

I((4:13)^2)  1 0.00471 0.004708  0.0912 0.7714

Residuals    7 0.36140 0.051629

Analysis of Variance Table

Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df    RSS Df Sum of Sq      F Pr(>F)

1      9 0.3736

2      7 0.3614  2  0.012202 0.1182 0.8903

[1] Site 6 spot 1 Background

Analysis of Variance Table


Response: coefs[i, ]

         Df   Sum Sq  Mean Sq F value  Pr(>F)

I(4:13)    1 0.071367 0.071367   7.039 0.02911 *

Residuals  8 0.081110 0.010139

Response: coefs[i, ]

           Df   Sum Sq  Mean Sq F value  Pr(>F)

I(4:13)      1 0.071367 0.071367  6.1625 0.04206 * downward trend in PC2

I((4:13)^2)  1 0.000044 0.000044  0.0038 0.95269

Residuals    7 0.081067 0.011581

Analysis of Variance Table


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df      RSS Df Sum of Sq      F Pr(>F)

1      9 0.152478

2      7 0.081067  2  0.071411 3.0831 0.1096
```



[1] Site 6 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.03852	0.038518	0.8398	0.3899
I((4:13)^2)	1	0.00874	0.008745	0.1907	0.6755
Residuals	7	0.32105	0.045864		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

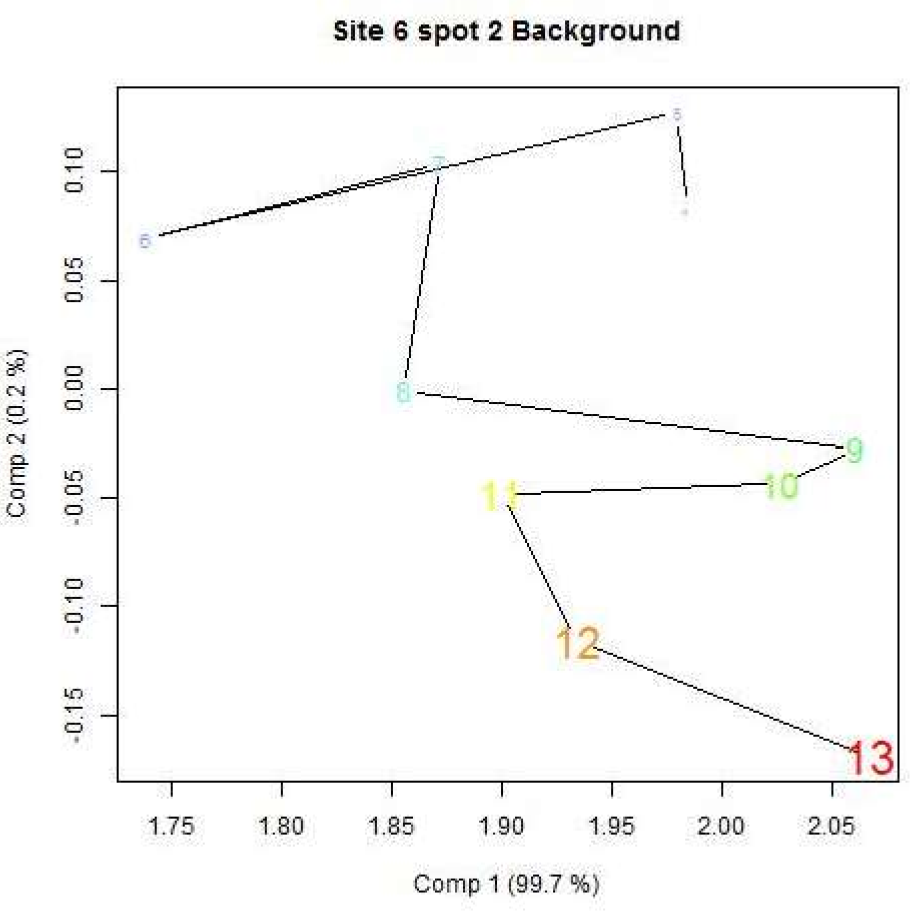
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.36831				
2	7	0.32105	2	0.047263	0.5153	0.6184

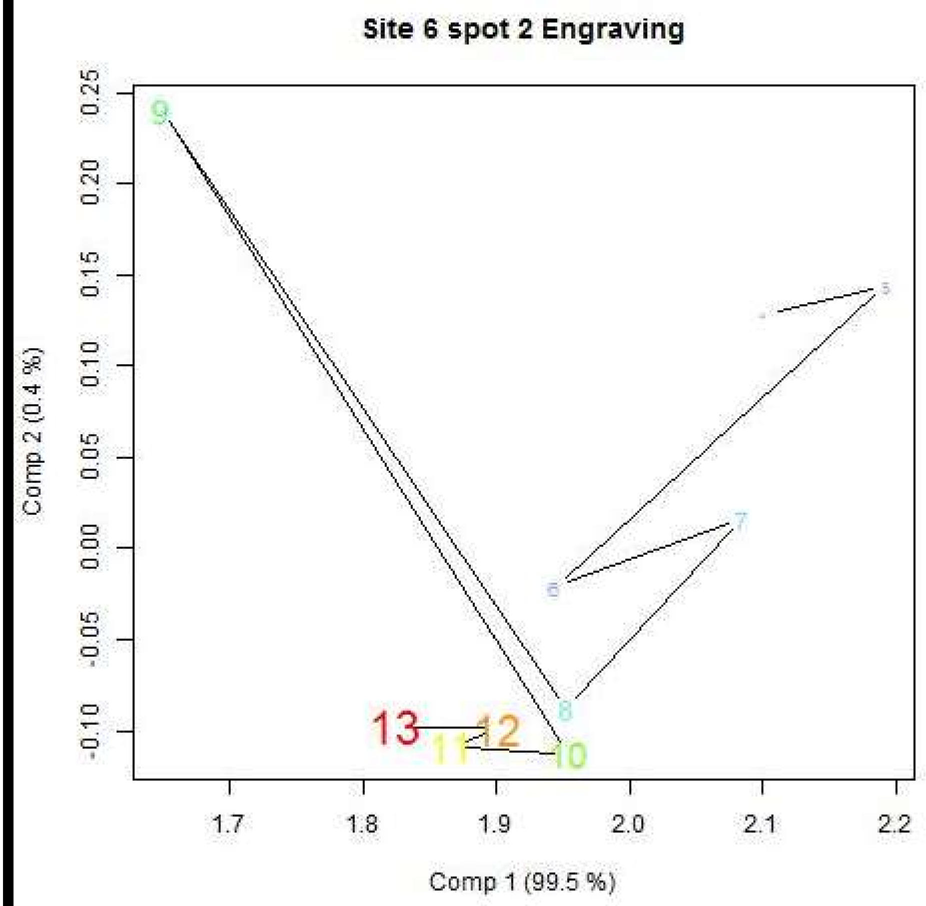
[1] Site 6 spot 1 Engraving

Analysis of Variance Table

```
Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)    1 0.071379 0.071379  7.6346 0.02456 *
Residuals  8 0.074794 0.009349
Response: coefs[i, ]
            Df   Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.071379 0.071379  6.7504 0.03552 * upward trend in PC2
I((4:13)^2)  1 0.000776 0.000776  0.0734 0.79423
Residuals    7 0.074018 0.010574
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df      RSS Df Sum of Sq      F  Pr(>F)
1      9 0.146173
2      7 0.074018  2  0.072155 3.4119 0.09239 .
```



```
[1] Site 6 spot 2 Background

Analysis of Variance Table

Response: coefs[i, ]

           Df   Sum Sq  Mean Sq F value Pr(>F)

I(4:13)     1 0.011085 0.011085  1.0292 0.3441

I((4:13)^2)  1 0.009806 0.009806  0.9105 0.3718

Residuals    7 0.075393 0.010771

Analysis of Variance Table

Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df      RSS Df Sum of Sq      F Pr(>F)

1      9 0.096285

2      7 0.075393  2  0.020891 0.9698 0.4248

[1] Site 6 spot 2 Background

Analysis of Variance Table


Response: coefs[i, ]

          Df   Sum Sq  Mean Sq F value    Pr(>F)

I(4:13)    1 0.076284 0.076284  66.952 3.711e-05 ***

Residuals  8 0.009115 0.001139

Response: coefs[i, ]

           Df   Sum Sq  Mean Sq F value    Pr(>F)

I(4:13)     1 0.076284 0.076284 81.6526 4.156e-05 *** downward trend in PC2

I((4:13)^2)  1 0.002575 0.002575  2.7565    0.1408

Residuals    7 0.006540 0.000934

Analysis of Variance Table


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df      RSS Df Sum of Sq      F    Pr(>F)

1      9 0.085399

2      7 0.006540  2  0.078859 42.205 0.0001243 ***
```



[1] Site 6 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.095249 0.095249 6.3379 0.03595 *

Residuals 8 0.120227 0.015028

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.095249 0.095249 6.3429 0.0399 * downward trend in PC1

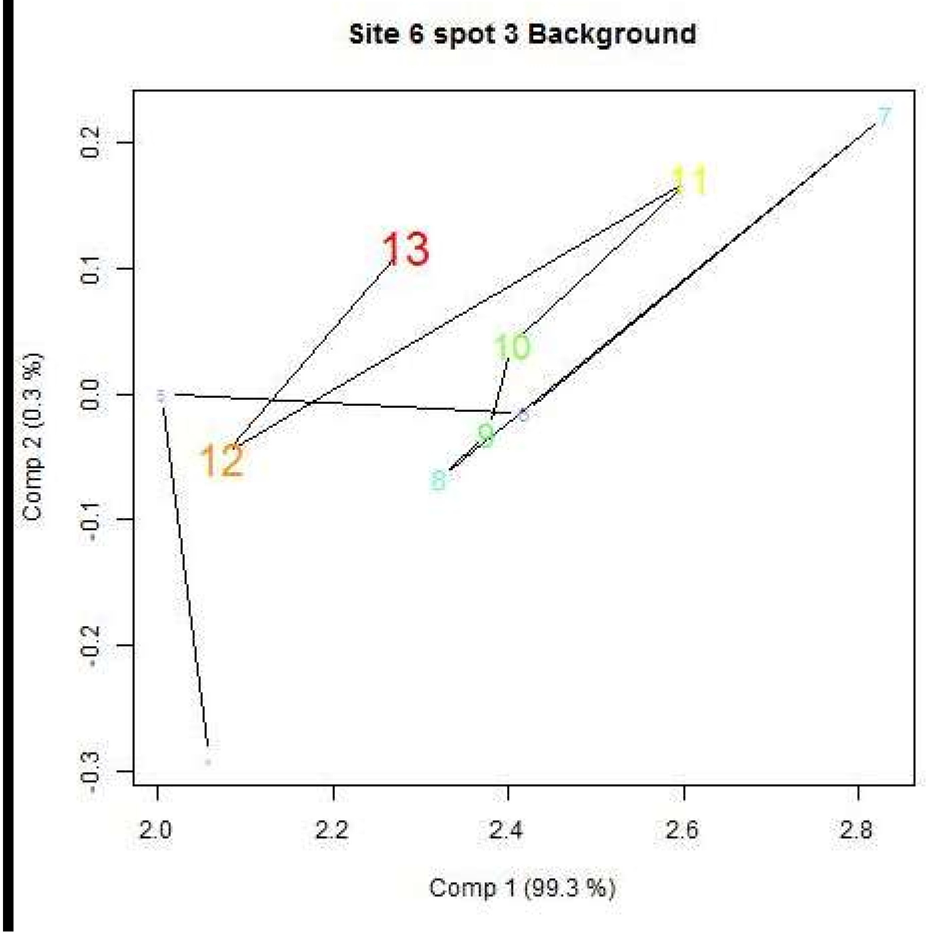
I((4:13)^2) 1 0.015111 0.015111 1.0063 0.3492

Residuals 7 0.105116 0.015017

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

```
Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F  Pr(>F)

1      9 0.21548

2      7 0.10512  2   0.11036 3.6746 0.08109 .

 [1] Site 6 spot 2 Engraving

Analysis of Variance Table


Response: coefs[i, ]

           Df   Sum Sq  Mean Sq F value  Pr(>F)

I(4:13)      1 0.054167 0.054167  4.0798 0.08315 .

I((4:13)^2)  1 0.000057 0.000057  0.0043 0.94959

Residuals    7 0.092937 0.013277

Analysis of Variance Table

Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df      RSS Df Sum of Sq      F Pr(>F)

1      9 0.147160

2      7 0.092937  2  0.054224 2.0421 0.2002
```



[1] Site 6 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:13)	1	0.01489	0.014892	0.2877	0.60830	
I((4:13)^2)	1	0.21497	0.214968	4.1535	0.08095	.
Residuals	7	0.36229	0.051756			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

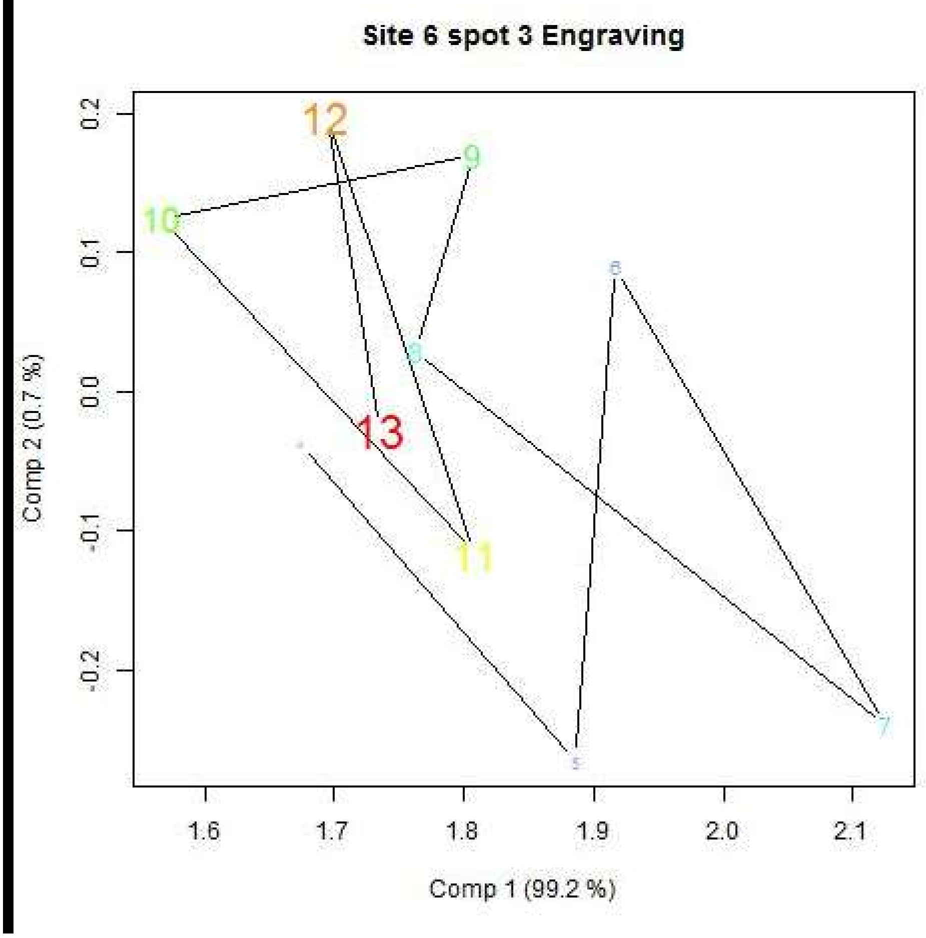
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

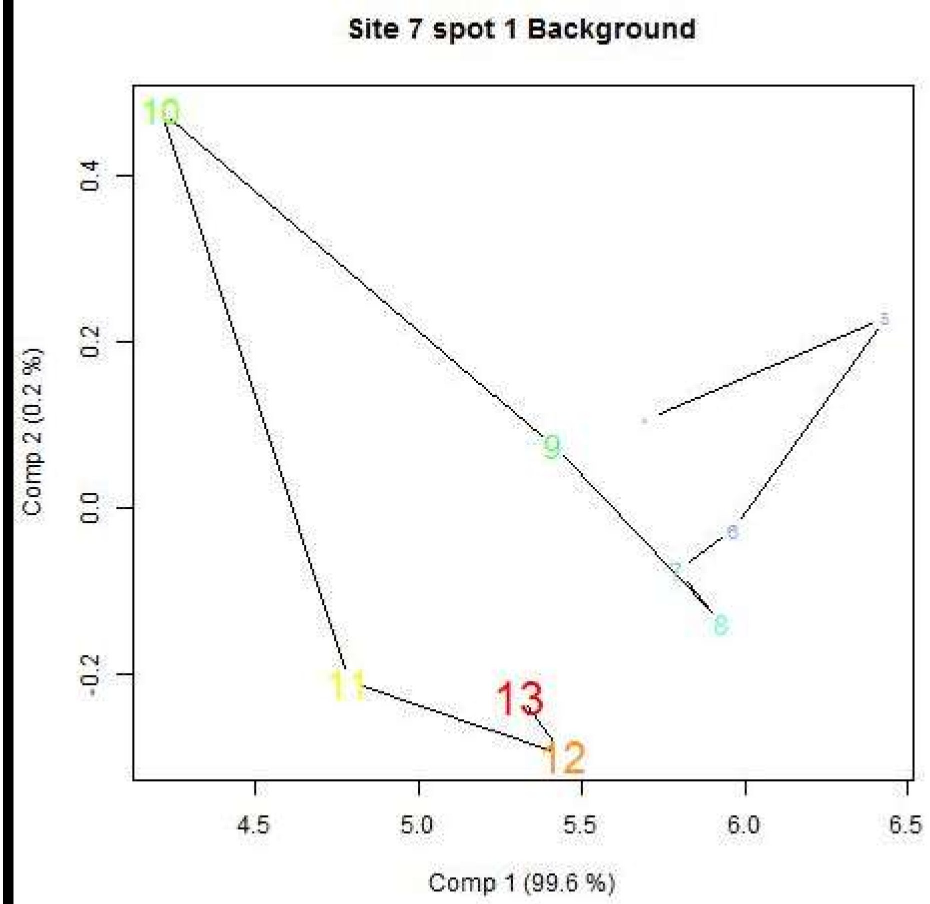
Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.59215				

```
2      7 0.36229  2   0.22986 2.2206 0.1791
[1] Site 6 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
           Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.042751 0.042751  2.4541 0.1612
I((4:13)^2)  1 0.021693 0.021693  1.2453 0.3013
Residuals    7 0.121942 0.017420
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
 Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.18639
2      7 0.12194  2  0.064444 1.8497 0.2265
```



```
[1] Site 6 spot 3 Engraving
Analysis of Variance Table

Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.026603 0.026603  1.0888 0.3314
I((4:13)^2)  1 0.016282 0.016282  0.6664 0.4412
Residuals    7 0.171032 0.024433
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.21392
2      7 0.17103  2  0.042886 0.8776  0.457
[1] Site 6 spot 3 Engraving
Analysis of Variance Table

Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.037624 0.037624  1.3825 0.2781
I((4:13)^2)  1 0.006862 0.006862  0.2521 0.6310
Residuals    7 0.190505 0.027215
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.23499
2      7 0.19051  2  0.044486 0.8173 0.4797
```




```
[1] Site 7 spot 1 Background
Analysis of Variance Table

Response: coefs[i, ]
           Df  Sum Sq Mean Sq F value  Pr(>F)
I(4:13)     1 1.40830 1.40830  4.6887 0.06708 .
I((4:13)^2)  1 0.10101 0.10101  0.3363 0.58015
Residuals    7 2.10251 0.30036
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 3.6118
```

2 7 2.1025 2 1.5093 2.5125 0.1505

[1] Site 7 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

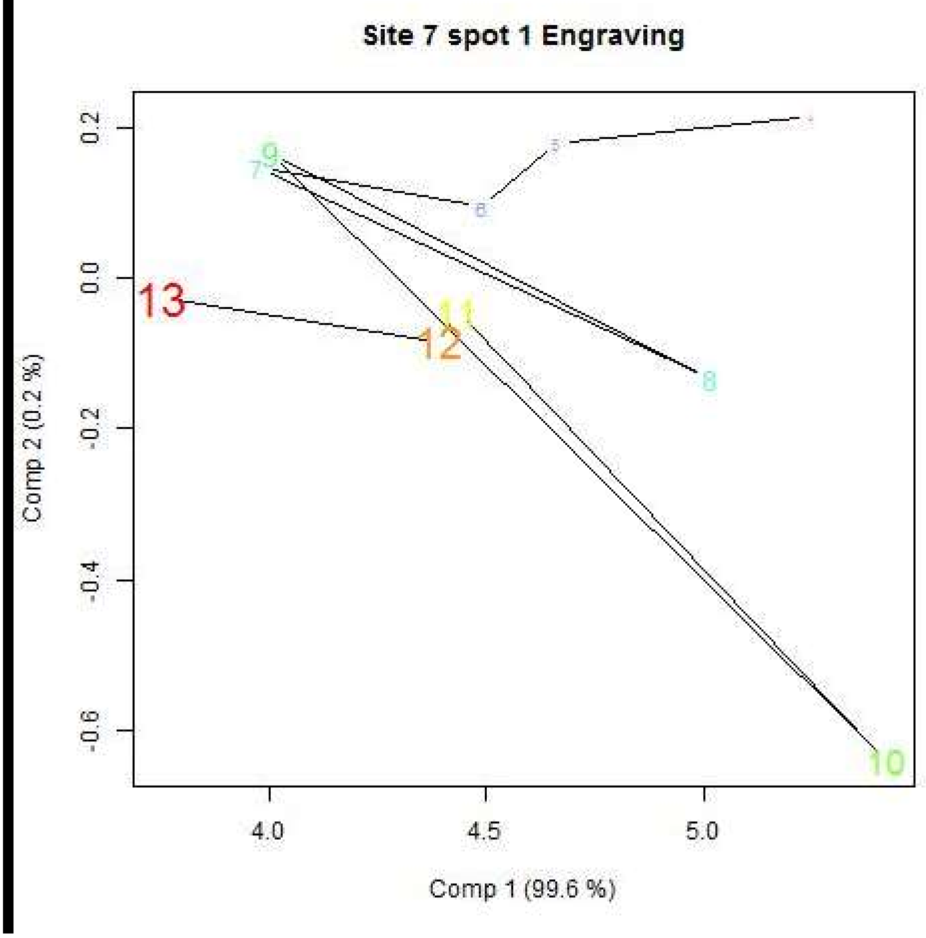
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.09828	0.098277	1.7777	0.2242
I((4:13)^2)	1	0.01856	0.018556	0.3357	0.5805
Residuals	7	0.38699	0.055284		

Analysis of Variance Table

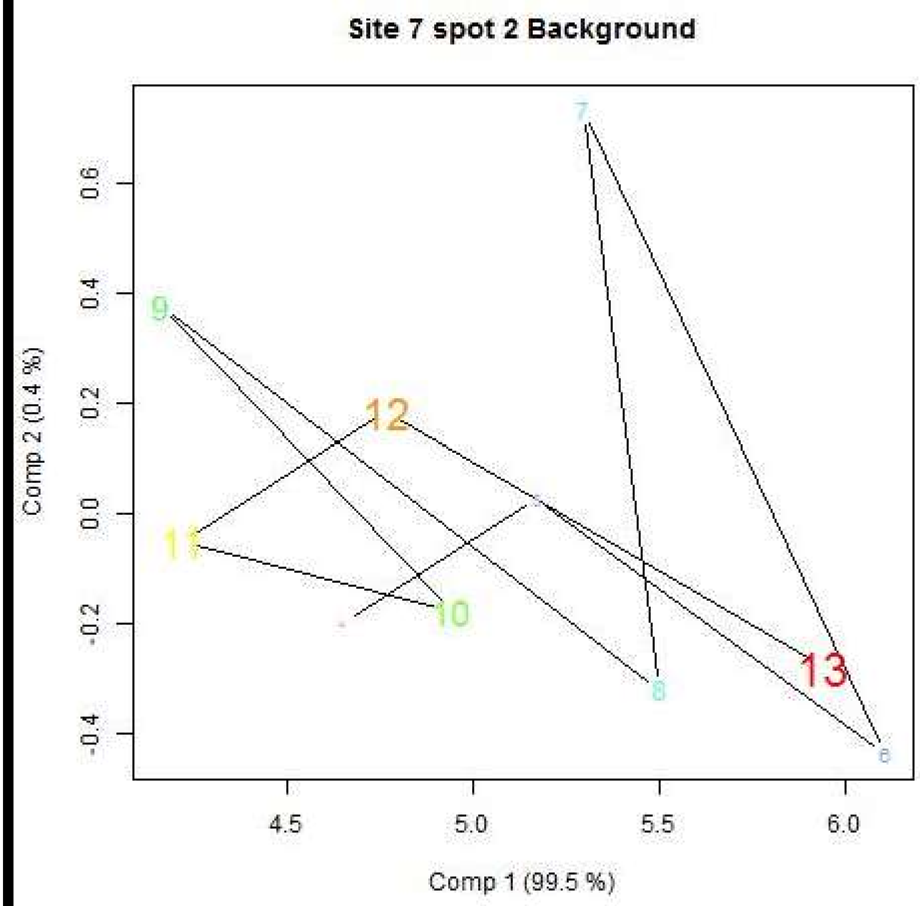
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	0.50382				
2	7	0.38699	2	0.11683	1.0567	0.3972



```
[1] Site 7 spot 1 Engraving
Analysis of Variance Table

Response: coefs[i, ]
           Df  Sum Sq Mean Sq F value Pr(>F)
I(4:13)     1 0.45755 0.45755  1.3885 0.2772
I((4:13)^2)  1 0.00877 0.00877  0.0266 0.8750
Residuals    7 2.30661 0.32952
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 2.7729
2      7 2.3066  2   0.46632 0.7076  0.525
[1] Site 7 spot 1 Engraving
Analysis of Variance Table

Response: coefs[i, ]
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.13906 0.139061  2.5508 0.1543
I((4:13)^2)  1 0.05237 0.052368  0.9606 0.3597
Residuals    7 0.38161 0.054516
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.57304
2      7 0.38161  2   0.19143 1.7557  0.241
```



[1] Site 7 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

```
            Df Sum Sq Mean Sq F value Pr(>F)
I(4:13)      1 0.0281 0.02810  0.0521 0.8260
I((4:13)^2)  1 0.1070 0.10701  0.1983 0.6695
Residuals    7 3.7769 0.53955
```

Analysis of Variance Table

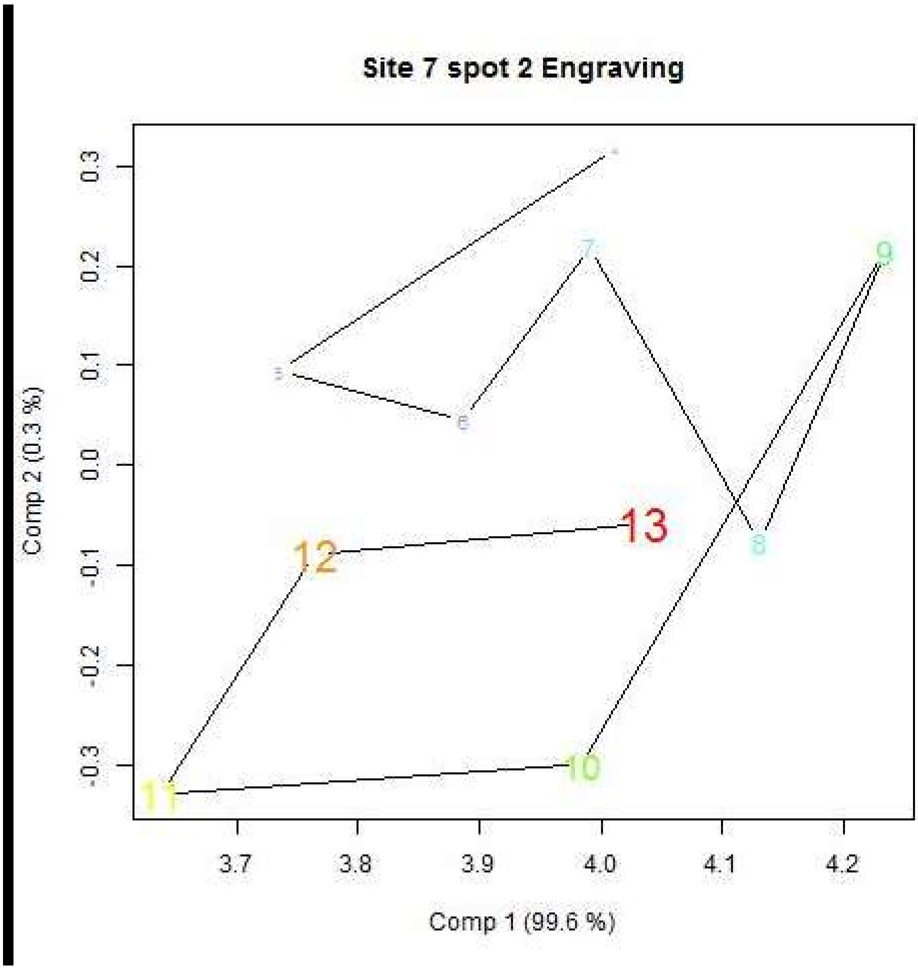
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 3.9120
2      7 3.7769  2   0.13511 0.1252 0.8842
```

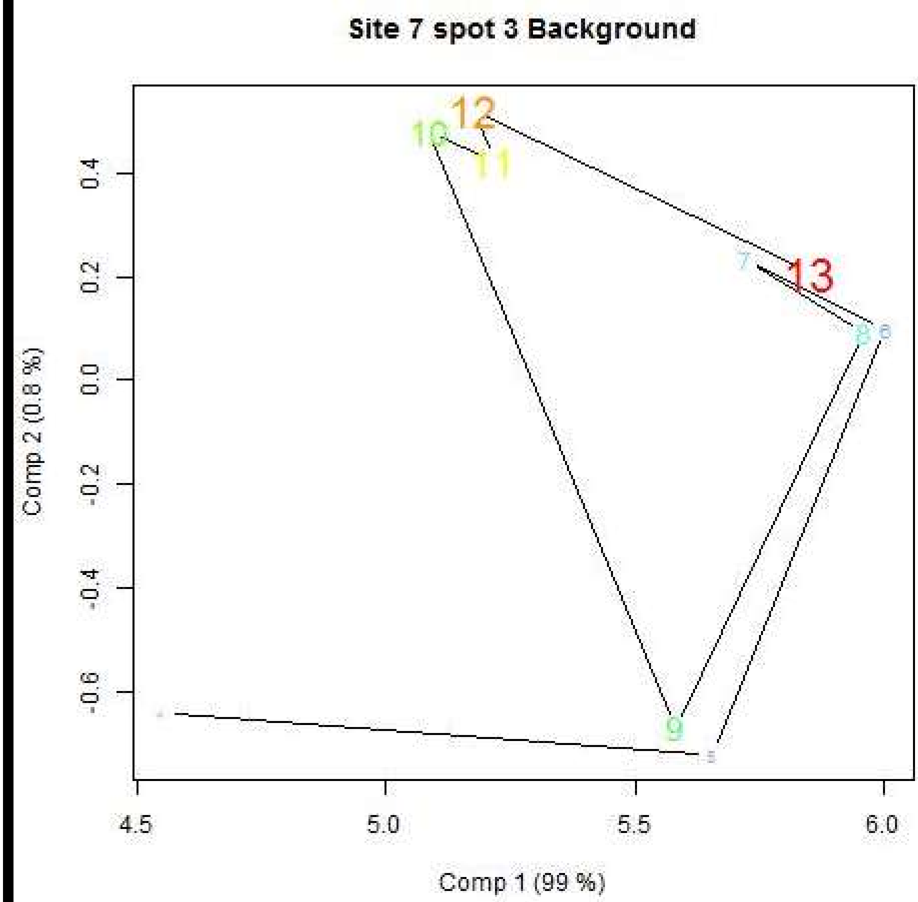
[1] Site 7 spot 2 Background

```
Analysis of Variance Table

Response: coefs[i, ]
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.00021 0.000208  0.0014 0.9713
I((4:13)^2)  1 0.11256 0.112558  0.7543 0.4139
Residuals    7 1.04452 0.149218
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df    RSS Df Sum of Sq      F Pr(>F)
1      9 1.1573
2      7 1.0445  2   0.11277 0.3779 0.6985
```



[1] Site 7 spot 2 Engraving

```
Analysis of Variance Table

Response: coefs[i, ]

          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.001685 0.001685  0.0412 0.8449
I((4:13)^2)  1 0.020088 0.020088  0.4917 0.5058
Residuals    7 0.285991 0.040856
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.30776
2      7 0.28599  2  0.021773 0.2665 0.7735
[1] Site 7 spot 2 Engraving
Analysis of Variance Table


Response: coefs[i, ]
        Df  Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)    1 0.18370 0.183704  6.2059 0.03745 *
Residuals  8 0.23681 0.029601
Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.183704 0.183704  5.8757 0.04582 * downward trend in PC2
I((4:13)^2)  1 0.017955 0.017955  0.5743 0.47330
Residuals    7 0.218856 0.031265
Analysis of Variance Table


Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq     F Pr(>F)
1      9 0.42052
2      7 0.21886  2   0.20166 3.225 0.1017
```



[1] Site 7 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:13)	1	0.01421	0.014206	0.0601	0.8134
I((4:13)^2)	1	0.24966	0.249659	1.0557	0.3384
Residuals	7	1.65546	0.236494		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	9	1.9193				
2	7	1.6555	2	0.26387	0.5579	0.5959

[1] Site 7 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.97681 0.97681 6.481 0.0344 *

Residuals 8 1.20576 0.15072

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13) 1 0.97681 0.97681 6.1044 0.04279 * upward trend in PC2

I((4:13)^2) 1 0.08564 0.08564 0.5352 0.48820

Residuals 7 1.12012 0.16002

Analysis of Variance Table

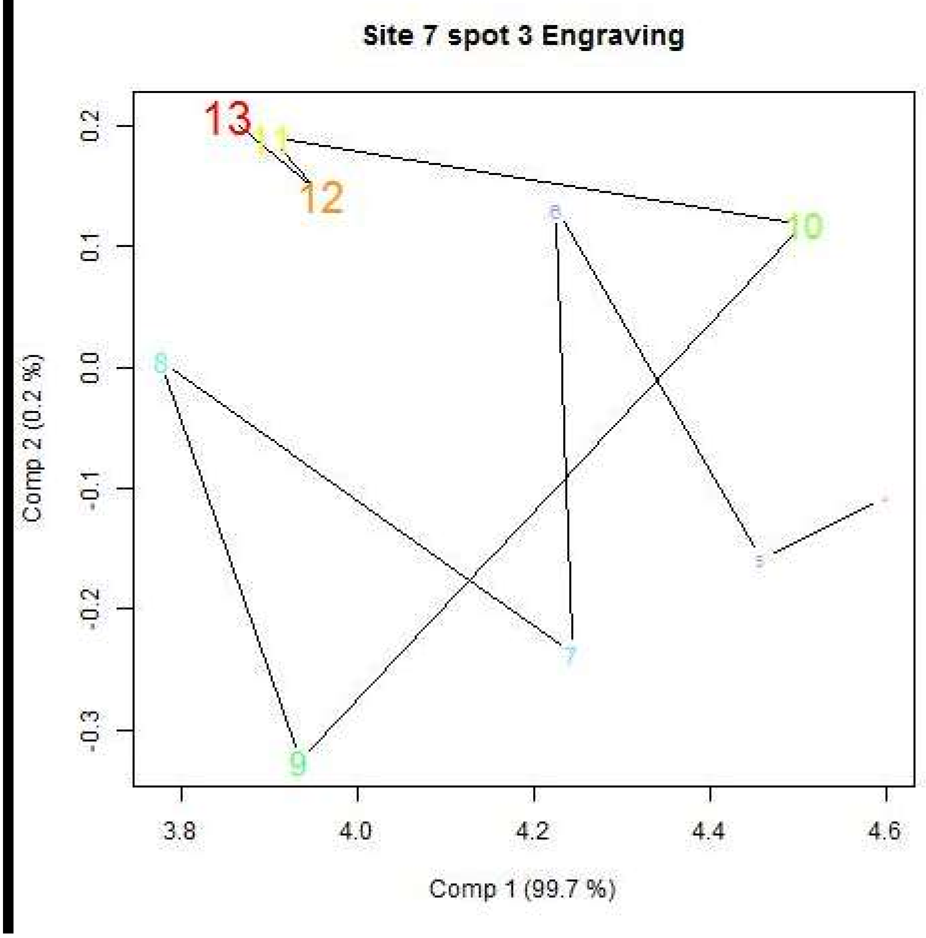
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

Res.Df RSS Df Sum of Sq F Pr(>F)

1 9 2.1826

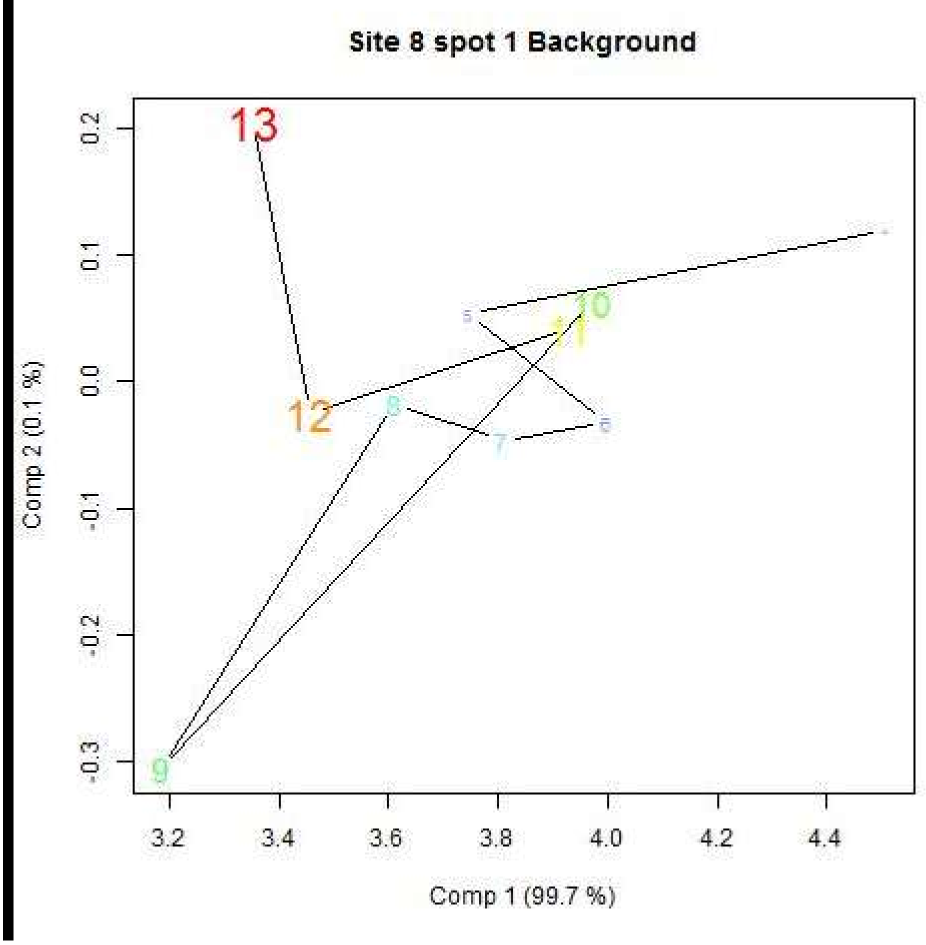
2 7 1.1201 2 1.0624 3.3198 0.09684 .



```
[1] Site 7 spot 3 Engraving

Analysis of Variance Table


Response: coefs[i, ]

          Df  Sum Sq Mean Sq F value Pr(>F)

I(4:13)    1 0.35825 0.35825  6.3698 0.0356 *

Residuals  8 0.44994 0.05624

Response: coefs[i, ]

            Df  Sum Sq Mean Sq F value  Pr(>F)

I(4:13)      1 0.35825 0.35825  6.1294 0.04247 * downward trend in PC1

I((4:13)^2)  1 0.04080 0.04080  0.6981 0.43101

Residuals    7 0.40914 0.05845

---

Analysis of Variance Table


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F  Pr(>F)

1      9 0.80819

2      7 0.40914  2   0.39905 3.4138 0.09231 .

 [1] Site 7 spot 3 Engraving

Analysis of Variance Table


Response: coefs[i, ]

            Df   Sum Sq  Mean Sq F value  Pr(>F)

I(4:13)      1 0.108402 0.108402  3.9031 0.08875 .

I((4:13)^2)  1 0.026979 0.026979  0.9714 0.35716

Residuals    7 0.194411 0.027773

Analysis of Variance Table


Model 1: coefs[i, ] ~ 1

Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)

  Res.Df     RSS Df Sum of Sq      F Pr(>F)
```

1   9 0.32979

2   7 0.19441 2   0.13538 2.4373 0.1573



[1] Site 8 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

          Df Sum Sq Mean Sq F value Pr(>F)

I(4:13)   1 0.48634 0.48634 4.5990 0.06917 .

I((4:13)^2) 1 0.07394 0.07394 0.6992 0.43068

Residuals   7 0.74024 0.10575

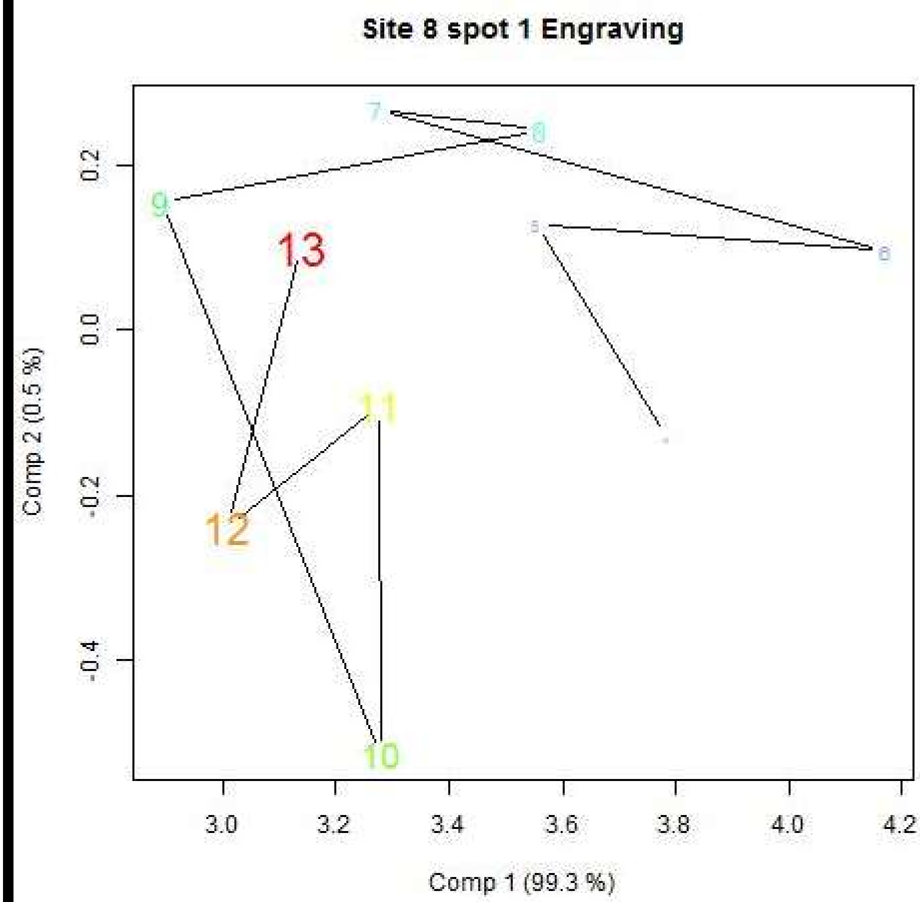
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
 Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 1.30052
2      7 0.74024  2   0.56028 2.6491 0.1391
[1] Site 8 spot 1 Background
Analysis of Variance Table

Response: coefs[i, ]
           Df   Sum Sq  Mean Sq F value  Pr(>F)
I(4:13)      1 0.001155 0.001155  0.0998 0.76131
I((4:13)^2)  1 0.078676 0.078676  6.7984 0.03505 *
Residuals    7 0.081009 0.011573
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
 Res.Df      RSS Df Sum of Sq      F  Pr(>F)
1      9 0.160840
2      7 0.081009  2  0.079831 3.4491 0.09068 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 8 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13)   1 0.65767 0.65767   8 0.0222 *

Residuals 8 0.65767 0.08221

Response: coefs[i,]

Df Sum Sq Mean Sq F value Pr(>F)

I(4:13)   1 0.65767 0.65767 7.2572 0.03091 * downward trend in PC1

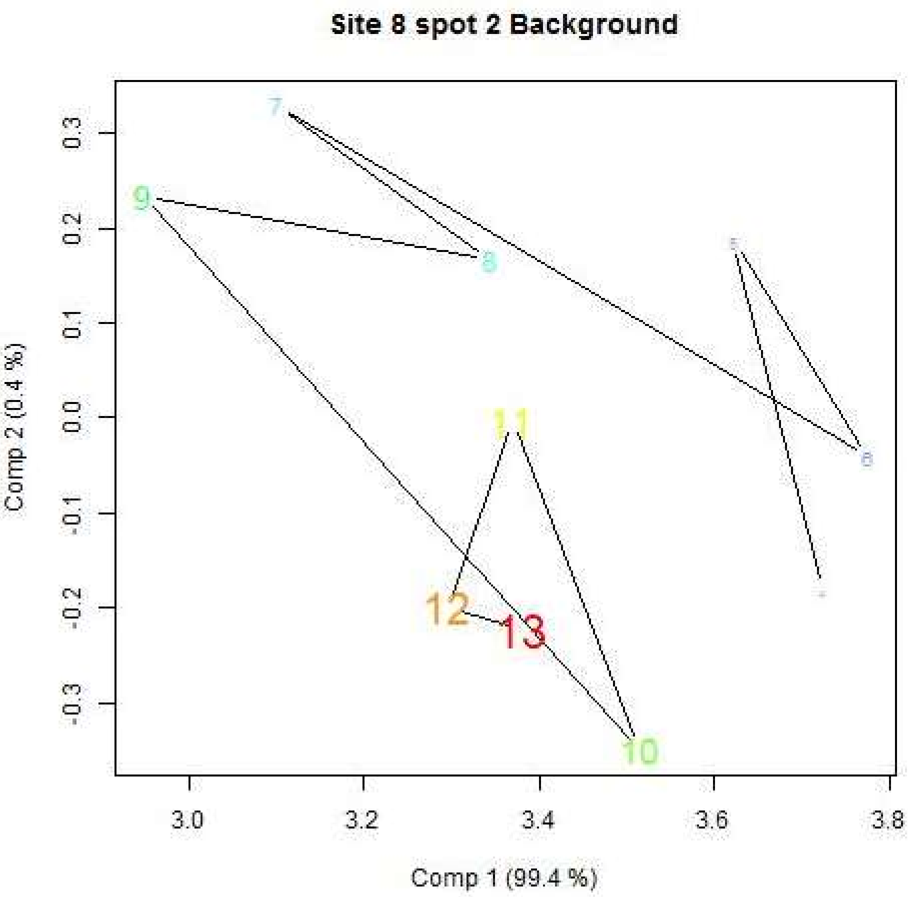
I((4:13)^2) 1 0.02331 0.02331 0.2572 0.62762

Residuals   7 0.63436 0.09062

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

```
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 1.31533
2      7 0.63436  2   0.68098 3.7572 0.0779 .
 [1] Site 8 spot 1 Engraving
Analysis of Variance Table

Response: coefs[i, ]
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.04505 0.045048  0.6561 0.4446
I((4:13)^2)  1 0.01177 0.011765  0.1714 0.6913
Residuals    7 0.48062 0.068660
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.53743
2      7 0.48062  2  0.056814 0.4137 0.6763
```



[1] Site 8 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

```
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)     1 0.13088 0.130876  2.6486 0.1477
I((4:13)^2)  1 0.14007 0.140071  2.8346 0.1361
Residuals   7 0.34590 0.049414
```

Analysis of Variance Table

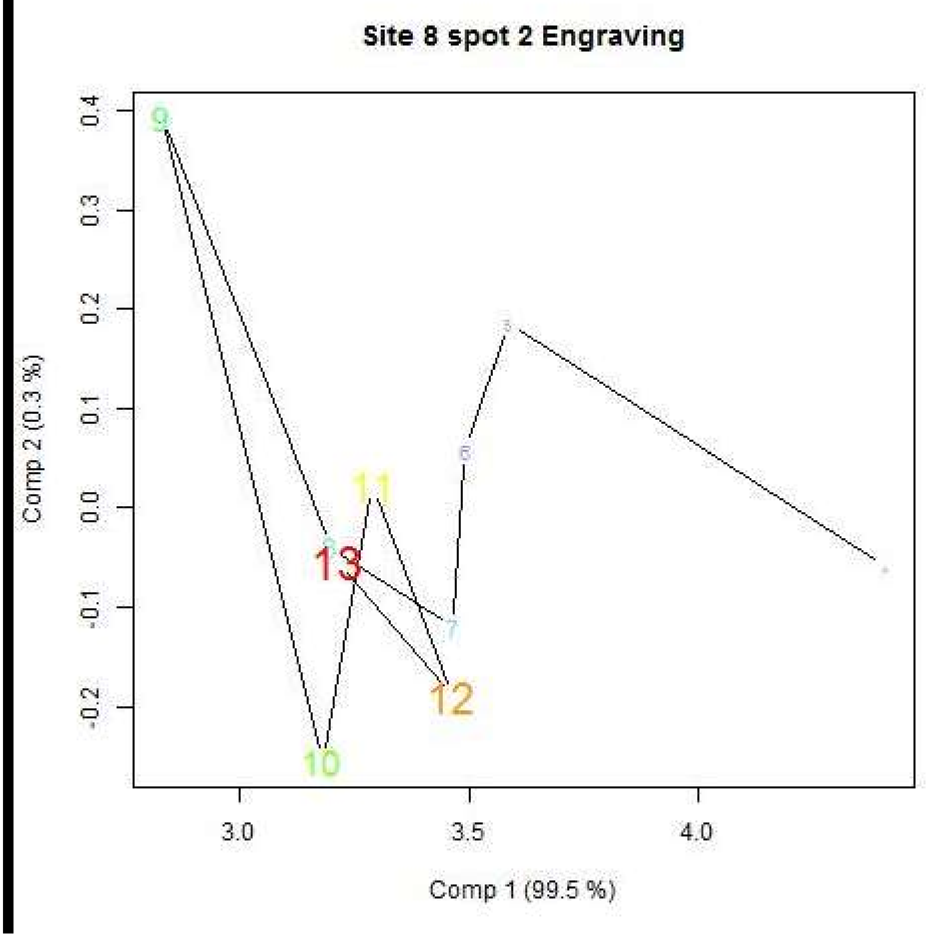
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.61684
2      7 0.34590  2   0.27095 2.7416  0.132
```

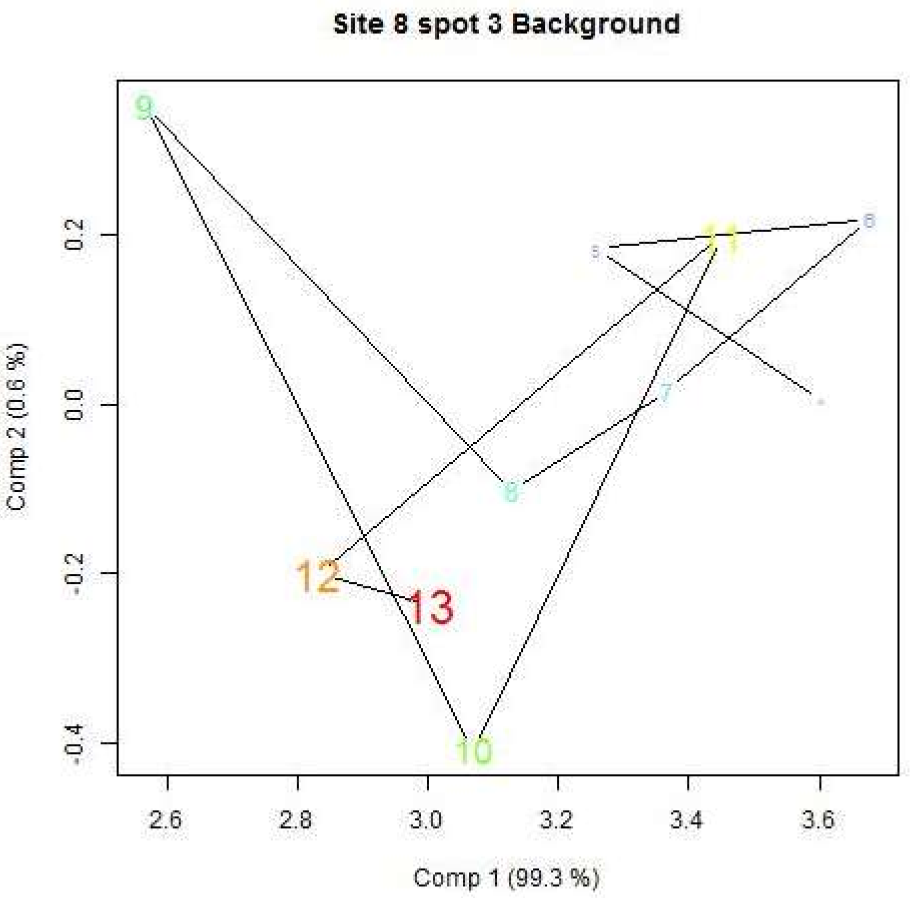
[1] Site 8 spot 2 Background

```
Analysis of Variance Table


Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.070497 0.070497  1.7550 0.2269
I((4:13)^2)  1 0.118024 0.118024  2.9382 0.1302
Residuals    7 0.281186 0.040169
Analysis of Variance Table


Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.46971
2      7 0.28119  2   0.18852 2.3466  0.166
```




```
[1] Site 8 spot 2 Engraving
```

```
Analysis of Variance Table


Response: coefs[i, ]
          Df  Sum Sq Mean Sq F value   Pr(>F)
I(4:13)      1 0.57720 0.57720  12.159 0.010170 * down-then-up trend in PC1
I((4:13)^2)  1 0.61131 0.61131  12.878 0.008874 **
Residuals    7 0.33229 0.04747
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Analysis of Variance Table


Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F   Pr(>F)
1      9 1.52080
2      7 0.33229  2    1.1885 12.518 0.004876 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
[1] Site 8 spot 2 Engraving
Analysis of Variance Table


Response: coefs[i, ]
          Df   Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.022662 0.022662  0.5549 0.4806
I((4:13)^2)  1 0.008661 0.008661  0.2121 0.6591
Residuals    7 0.285895 0.040842
Analysis of Variance Table


Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.31722
2      7 0.28589  2  0.031323 0.3835  0.695
```



[1] Site 8 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

```
            Df  Sum Sq Mean Sq F value  Pr(>F)
I(4:13)      1 0.36669 0.36669  3.8472 0.09063 .
I((4:13)^2)  1 0.05086 0.05086  0.5336 0.48882
Residuals    7 0.66718 0.09531
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

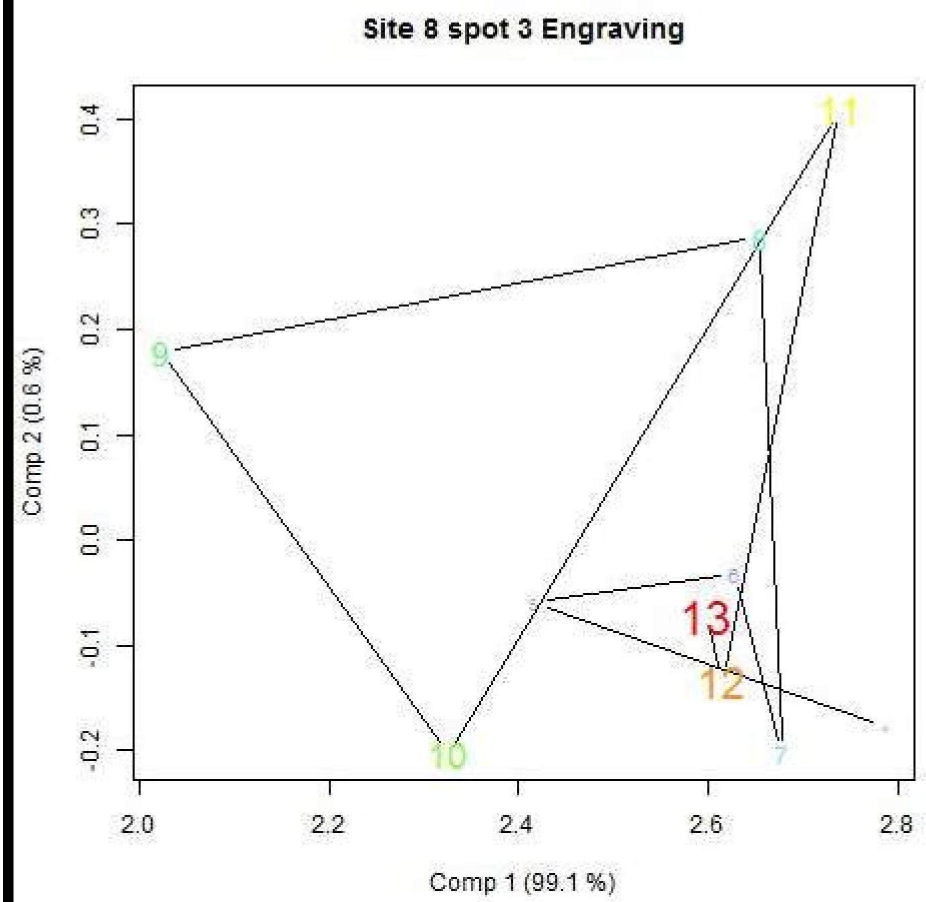
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
```

```
1      9 1.08473
2      7 0.66718  2   0.41754 2.1904 0.1825
[1] Site 8 spot 3 Background
Analysis of Variance Table

Response: coefs[i, ]
            Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.10057 0.100567  1.7894 0.2228
I((4:13)^2)  1 0.02108 0.021078  0.3750 0.5596
Residuals    7 0.39340 0.056200
Analysis of Variance Table

Model 1: coefs[i, ] ~ 1
Model 2: coefs[i, ] ~ I(4:13) + I((4:13)^2)
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.51505
2      7 0.39340  2   0.12164 1.0822 0.3895
```



[1] Site 8 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
           Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.00626 0.006261  0.1127 0.7469
I((4:13)^2)  1 0.08207 0.082072  1.4777 0.2635
Residuals    7 0.38878 0.055540
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.47712
2      7 0.38878  2  0.088333 0.7952 0.4884
```

[1] Site 8 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
          Df  Sum Sq  Mean Sq F value Pr(>F)
I(4:13)      1 0.01926 0.019265  0.3974 0.5484
I((4:13)^2)  1 0.06339 0.063390  1.3077 0.2904
Residuals    7 0.33932 0.048474
```

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:13) + I((4:13)^2)

```
  Res.Df     RSS Df Sum of Sq      F Pr(>F)
1      9 0.42197
2      7 0.33932  2  0.082655 0.8526 0.4663
```