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Burrup Peninsula Aboriginal Petroglyphs: Colour Change & Spectral Mineralogy 2004–2014

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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 Monitoring Management Committee (BRAMMC) 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 Technical Working Group (BRATWIG) 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 11 years (2004 to 2014), 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 11 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 10th 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. Previously, the following analysis for colour measurements was carried out:

1. Replicate sample data was collected in L*a*b* numerical format.
2. Measurements at a single spot were averaged and reported.
3. Colour difference between background and engraving was 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 were plotted and a trend line reported.

In 2013, analysis of the data as outlined in the 4 points above was 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 from 2013. This analysis approach has continued in 2014.

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 from 2013 this spectrophotometer was used to collect all data.

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, and in 2013 a PCA multivariate analysis was performed on averaged annual measurements. This analysis was intended to demonstrate whether a systematic change was observed from year to year. Each spot was analysed and plotted individually. This analysis was repeated on the 2014 data presented in this report.

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 11 years no observed accelerated colour contrast change was detected at the Southern test sites, when compared with the Northern control sites.

In 2014, the rock art monitoring project expanded at the request of Yara Pilbara Nitrates Pty Ltd (YPNPL). The company is currently building a Technical Ammonium Nitrate Production Facility Project (or TAN) on the Burrup Peninsula, and to adhere to the requirements of the Environment Protection and Biodiversity Conservation Act 1999, YPNPL needed to engage a heritage monitor to survey the rock art sites within a two kilometre radius of the project site. CSIRO has been a heritage monitor for the West Australian Government Department for Environmental Regulation for the monitoring of the Burrup petroglyphs for the last decade and was considered appropriate to be the heritage monitor for YPNPL.

The rock art study dedicated for the TAN Project required the heritage monitoring of petroglyphs sites within 2km of the plant site. Selected sites were determined in consultation with members of Murujuga Aboriginal Corporation to respect the cultural laws of the traditional owners for the entitlement of access. The selected petroglyphs were firstly evaluated for their appropriateness for scientific study, including petroglyph size and quality, direction of exposure, elevation, dominant winds direction within 2 km of the TAN project location.

From the six selected monitoring sites; three were already part of the decade-old and ongoing BRATWG monitoring program and an additional three sites were also selected. After initial monitoring in February 2014, the three new sites have become part of the BRATWG monitoring program. On each monitored petroglyph panel, eight (8) sampling areas or "spots" were selected; four (4) areas classified as 'engraving' – defined by the pecking marks that constitute the image and four (4) areas classified as 'background' – a section of the adjacent rock surface unmarked by the petroglyph.

As with the existing monitoring study, three types of measurements were carried out: (a) colour contrast monitoring and (b) spectral mineralogy to assess the surface of the petroglyphs. The measurements collected in February 2014 will be used as the baseline dataset to monitor possible changes that could occur in the next three years.

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 Environmental Regulation (DER), CSIRO has measured the colour of selected petroglyphs on the Burrup Peninsula over a period of eleven 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 11 years (2004 to 2014 - 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; Markley et al., 2013), the petroglyphs at 7 specially selected sites in the Burrup Peninsula (Western Australia) were measured using reflectance spectroscopy and colour spectrophotometry. In 2014, three (3) additional sites located within a 2km radius of the Yara Pilbara Nitrates Pty Ltd (YPNPL) Technical Ammonium Nitrate Production Facility Project (or TAN) were added to the monitoring program. From 2004 to 2012, three spots on each engraving and 3 spots on each background rock were measured *in situ* using an ASD spectrometer and a spectrophotometer, with a 4th engraving and background spot added in 2013. The spectral measurements were co-located with the colour measurements and acquired simultaneously. Initially, at each engraving and background spot seven spectra were acquired and averaged, with this increasing to 21 repeat measurements at each spot in 2005 to improve the statistical robustness of the data. 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 11 years. The eleven-year study (2004-2014) has assessed the mineralogy to monitor and explain the mineralogical changes (if any) of seven rock art sites in the Burrup Peninsula, and an additional three sites in 2014, along with analysing any colour differences or changes.

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 'such 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 2014.

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

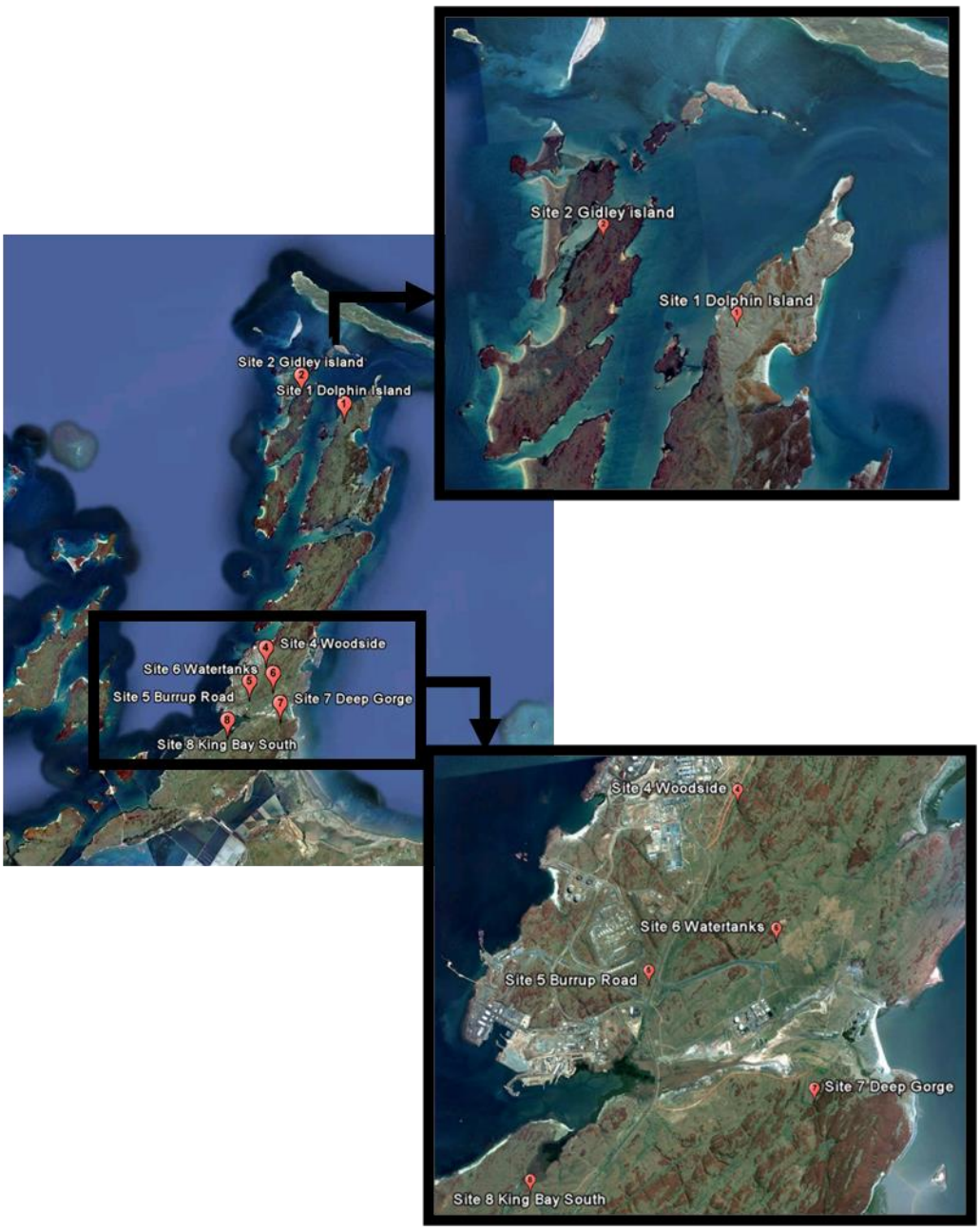


Figure 1: Google Earth® maps of the Burrup Peninsula with the location of the petroglyphs.

The Gidley granophyre (Sites 2, 4, 5, 6, 8 and 21) consists of intergrowth of primary minerals such as quartz and alkali feldspar and, albite and magnetite. Secondary minerals include chlorite, epidote, stilpnomelane, sphene, actinolite, phengite and calcite. Accessory minerals include apatite, rutile and zircon.

The Gidley Gabbro (Sites 1, 7, 22 and 23) shows very little deformation and the relative percentage of each of the minerals composing the gabbro differs marginally from site 1 to site 7 with quartz, feldspar, actinolite and chlorite dominating. Minor minerals include augite, epidote-clinozoisite and muscovite. Trace minerals include ilmenite, sphene, barite, apatite and rutile.

For the 3 additional sites included as part of this study for the Yara Pilbara Nitrates Pty Ltd (YPNPL) Technical Ammonium Nitrate Production Facility Project, a similar approach was adopted where consideration is given to the location of the plant site and its 2 km radius relative to the wind main directions through the year (Figure 2). The ultimate decision was made by the Elders of the Murujuga Aboriginal Corporation. The monitoring consists of six monitoring sites within 2km of the plant site. Three existing sites labelled 5 or Burrup Road, 6 or Water Tanks and 7 or Deep Gorge (Figure 2) from the (BRATWG) monitoring program and three additional monitoring sites within 2km of plant site labelled 21 or Yara West, 22 or Yara North East and 23 or Yara East (Figure 2). In July 2014, the three additional sites (21, 22 and 23) became part of the BRATWG monitoring program with a new total of 10 monitoring sites.

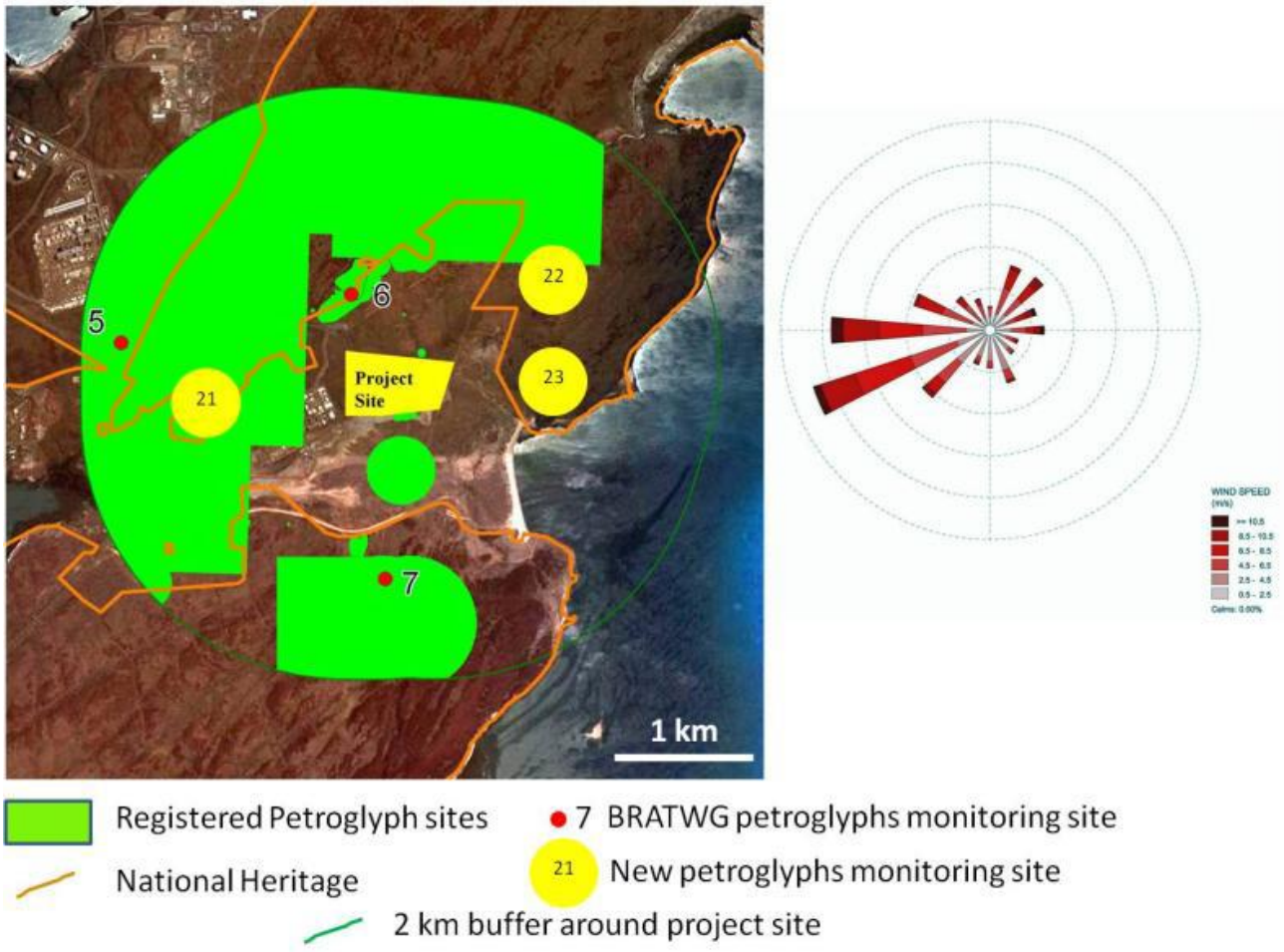


Figure 2: New sites (Yellow numbers) with dominant wind directions and speed.

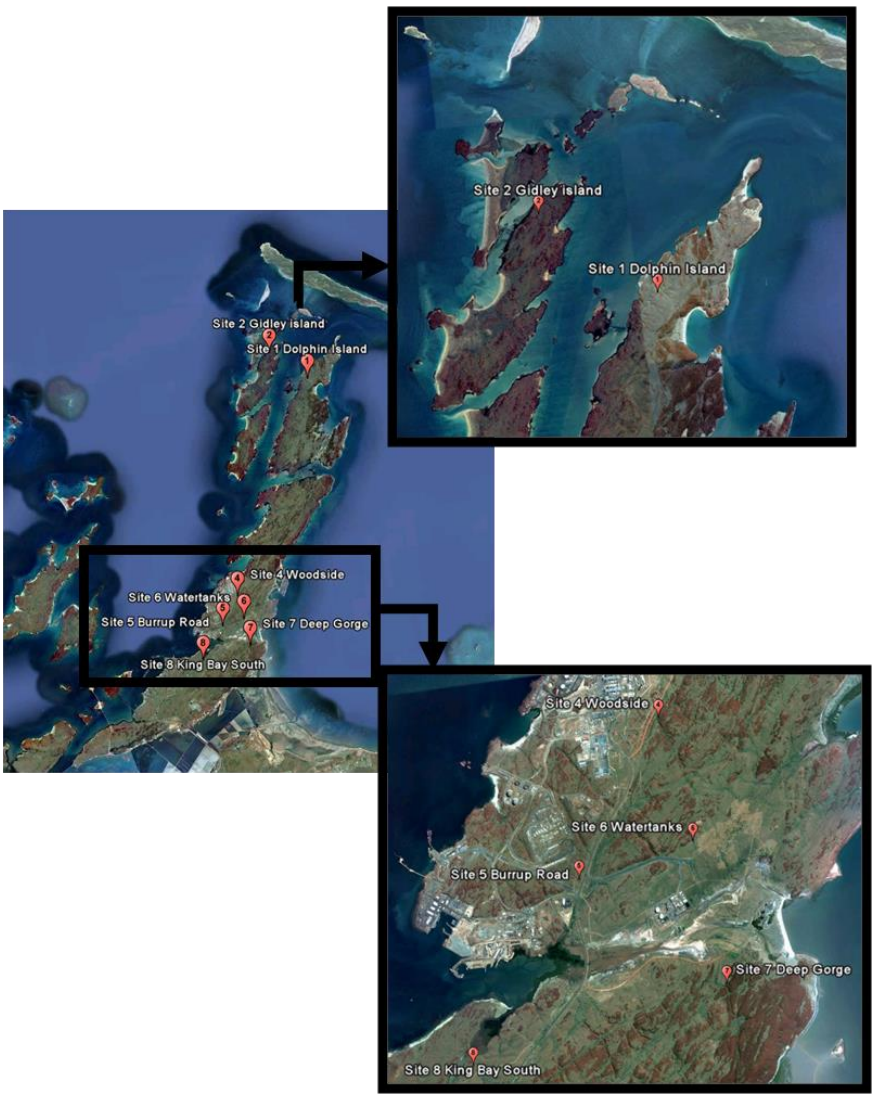


Figure 3: Google Earth® maps of the Burrup Peninsula with the petroglyphs location.

Table 2: Coordinates (GDA 94, Zone 50) of the 6 sites measured for the TAN Monitoring project

Site	Site name	Coordinates (GDA 94, Zone 50)	
5	Burrup Rd	475,959	7,719,771
6	Water Tanks	477,698	7,720,137
7	Deep Gorge	477,956	7,717,987
21	Yara West	476,558	7,719,223
22	Yara North East	479,112	7,720,155
23	Yara East	478,849	7,719,565

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.

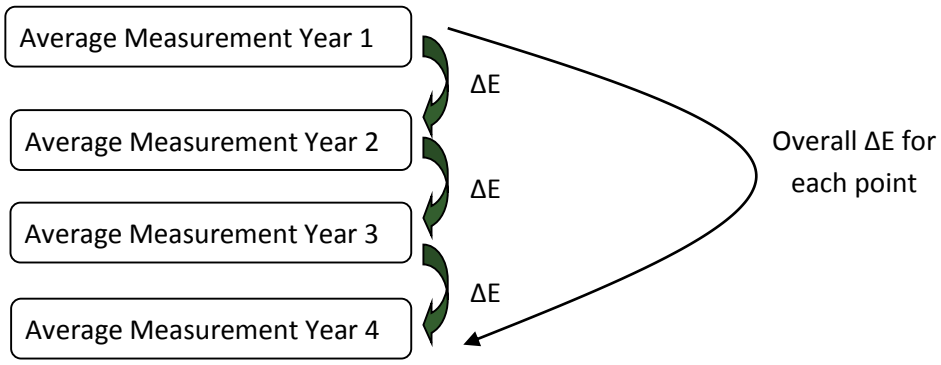
3.2 Experimental Methodology

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[1]) with inbuilt spectral illuminants: CIE illuminant A, D65 and F2 (see Figure 4 and Table 4). 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 4: Portable spectrophotometer used for colour measurements.

[1] 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 ΔE, 1σ	0.02 ΔE, 1σ	CIELab/Ch; Lab(h); XYZ; Yxy; RxRyRz	ΔE; ΔE(h); ΔEFMC2; ΔE94; ΔECMC; Component differences	YIE313; YID1925; WIE313; CIE; Berger; Color strength; Opacity; Metamerism	20 nm
Observer	**Language**	**Power Supply**	**Operating Temperature**	**Illuminants**	**Spectral Range**
2°; 10°	English; German; French; Italian; Spanish; Japanese	4 AA alkaline; NiCd or MH	50 to -110 °F (10 to -42 °C)	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 °C (95 °F)			

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 5). 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 5. A comparison of measurements obtained by the two instruments on rock surfaces is presented in Table 6.

Figure 5: Konica Minolta CM-700d spectrophotometer.

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

Colour Space	**Observer**	**Illuminant**	**Measurement/ illumination area**
L*a*b*	10^{O}	D65 –simulated daylight	SAV: Φ3 mm/Φ6 mm
Light source	**Measurement time**	**Repeatability**	
Pulsed xenon lamp (with UV cut filter)	Approx. 1 second	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 measurements are 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 – 2014, allowing a conversion factor to be determined that can be applied to BYK data collected 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 from 2013 were collected using the Konica Minolta spectrophotometer. For the results presented in this report, years 2009 - 2014 were collected using the KM spectrophotometer, while 2004 -2008 were BYK spectrophotometer data. A conversion model was applied to the BYK data to make it comparable with the data of the current year which was collected with the KM spectrophotometer[2].

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 4th engraving and background analysis spots, new in 2013, 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.

[2] At the request of Bill Carr of BRATWG, the 2004 to 2008 data was not converted to be directly comparable with data collected from 2009 – 2014 using the Konica Minolta spectrophotometer. Therefore all comparison of data presented is only between data collected by the same instrument, with the exception of comparing the current year's data with a converted 2004 data set.

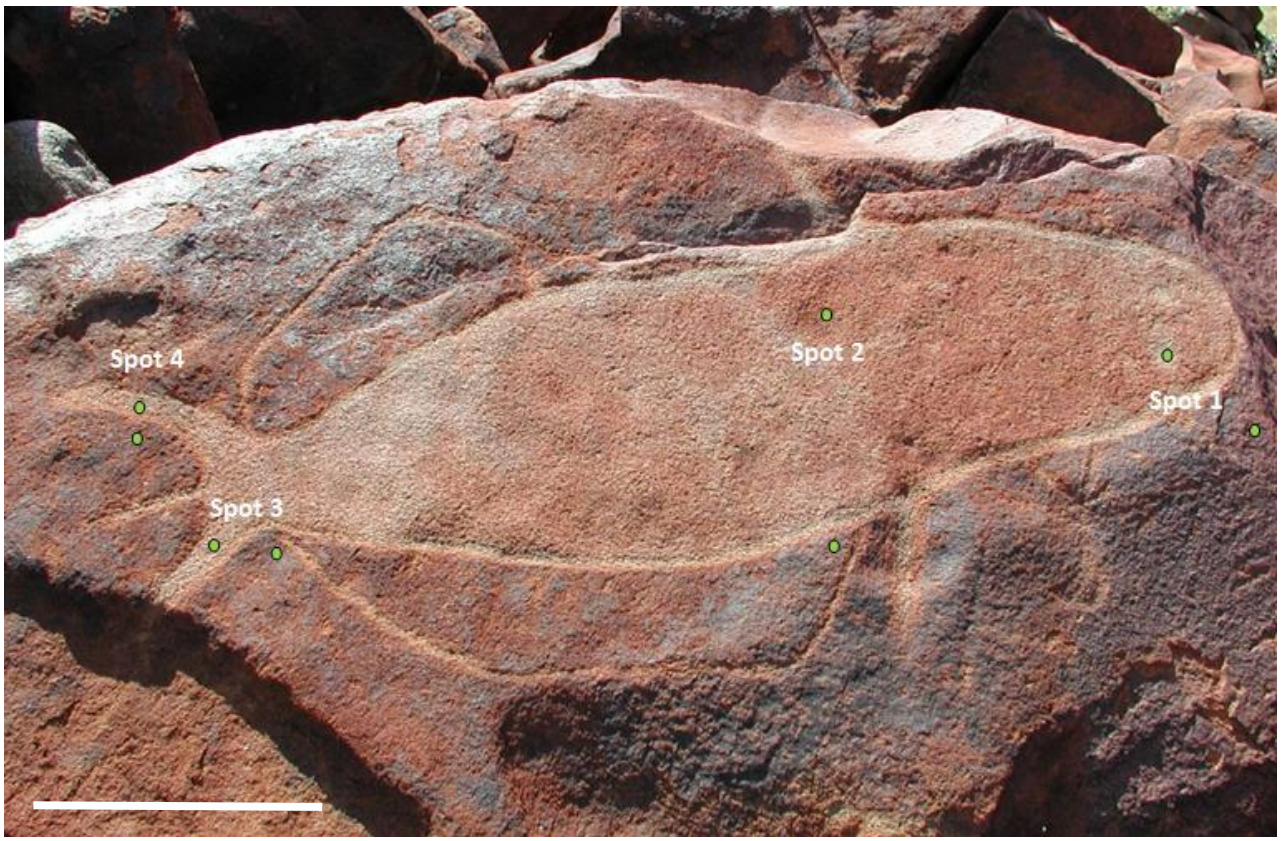


Figure 6: Site 1- Dolphin Island (White scalebar is 50 cm).

Table 6: Average Colour Measurements for Site 1 – Dolphin Island (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 1 Spot 1 Engraving				
Average 2014	41.80	8.78	15.97	1.34
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	
Average 2008	19.10	4.54	12.45	2.34
Average 2007	17.16	5.71	13.03	2.39
Average 2006	16.79	3.83	11.59	3.04
Average 2005	14.97	6.08	12.53	2.16
Average 2004	14.32	8.08	13.00	0.00
Site 1 Spot 1 Background				
Average 2014	33.42	10.66	9.32	1.15
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	
Average 2008	29.91	11.10	11.22	1.72
Average 2007	28.24	10.69	11.14	1.16
Average 2006	28.97	10.29	10.33	1.84
Average 2005	27.66	11.26	11.20	2.24
Average 2004	29.87	11.20	10.79	0.00
Site 1 Spot 2 Engraving				
Average 2014	33.26	16.88	18.28	2.55
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	
Average 2008	14.96	11.17	13.53	3.52
Average 2007	12.13	9.76	11.98	4.89
Average 2006	8.37	8.22	9.26	1.84
Average 2005	7.91	9.84	9.99	0.69
Average 2004	8.43	9.62	9.59	0.00
Site 1 Spot 2 Background				
Average 2014	31.65	9.11	9.24	1.58
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	
Average 2008	26.35	9.51	11.43	6.11
Average 2007	20.96	7.06	9.92	8.54
Average 2006	28.82	10.21	11.06	7.88
Average 2005	20.98	9.46	11.46	6.74
Average 2004	27.66	10.35	11.87	0.00

Site 1 Spot 3 Engraving				
Average 2014	38.66	14.47	19.18	1.21
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	
Average 2008	32.98	11.15	17.56	6.37
Average 2007	26.72	10.16	16.94	3.60
Average 2006	23.22	10.68	16.27	3.16
Average 2005	25.67	12.25	17.51	3.02
Average 2004	28.67	12.12	17.18	0.00
Site 1 Spot 3 Background				
Average 2014	29.49	12.47	12.96	0.72
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	
Average 2008	15.14	7.48	10.02	4.29
Average 2007	19.09	8.97	10.76	6.43
Average 2006	13.07	7.30	9.25	2.43
Average 2005	11.45	8.75	10.33	2.44
Average 2004	13.42	7.98	9.11	0.00
Site 1 Spot 4 Engraving				
Average 2014	35.08	12.09	16.57	4.28
Average 2013	38.39	13.95	18.56	
Site 1 Spot 4 Background				
Average 2014	28.73	12.41	12.42	2.10
Average 2013	29.49	11.17	10.91	

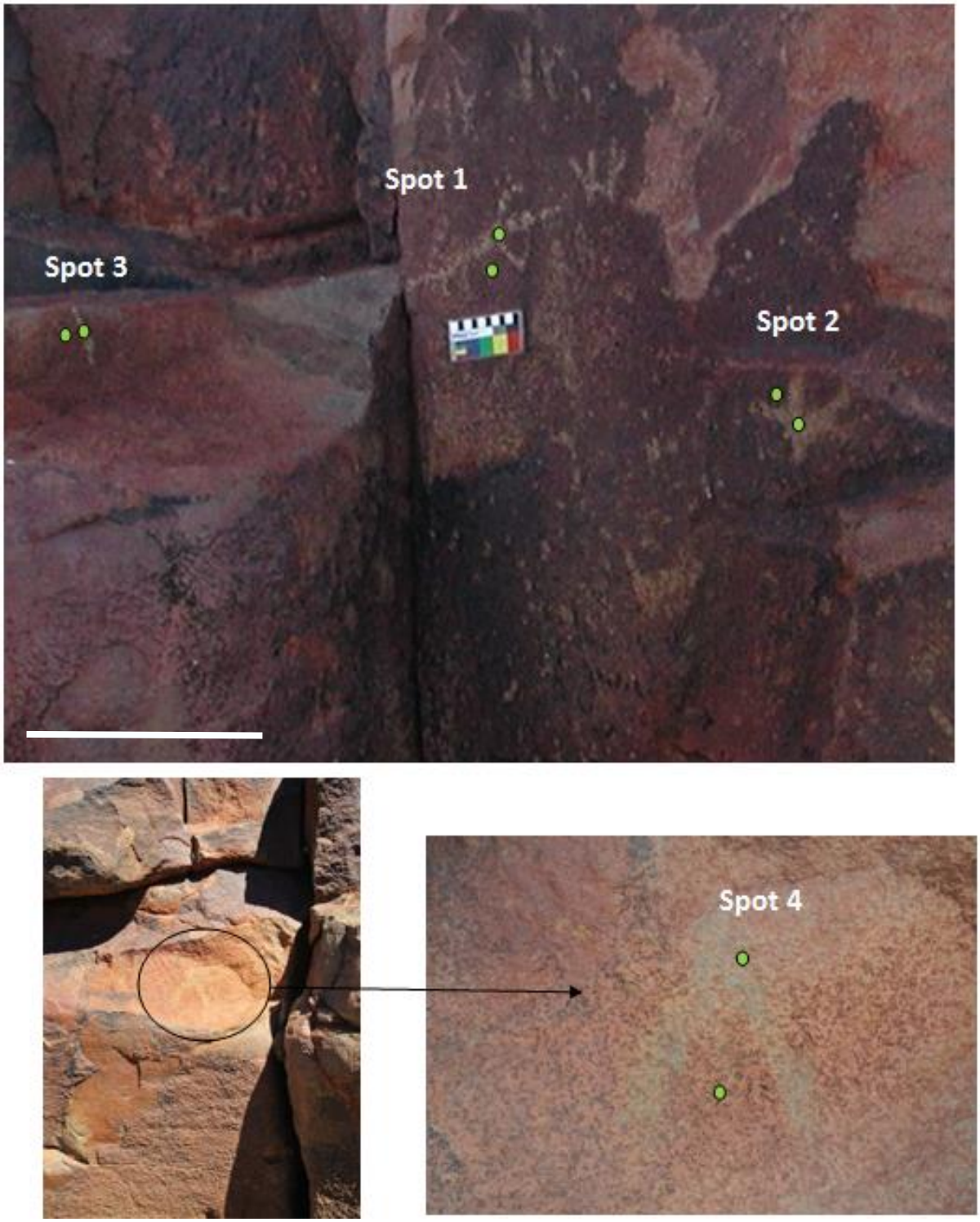


Figure 7: Site 2 – Gidley Island (white scalebar is 10 cm).

Table 7: Average Colour Measurements for Site 2 – Gidley Island (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 2 Spot 1 Engraving				
Average 2014	38.34	8.70	16.34	1.97
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	
Average 2008	32.99	7.11	16.02	2.23
Average 2007	31.06	7.44	14.96	3.72
Average 2006	34.10	7.79	17.07	1.62
Average 2005	33.58	9.26	17.50	2.29
Average 2004	31.90	8.96	15.98	0.00
Site 2 Spot 1 Background				
Average 2014	32.63	10.43	13.88	2.36
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	
Average 2008	28.91	9.53	13.25	4.47
Average 2007	25.42	7.93	10.97	1.86
Average 2006	26.54	9.16	11.82	2.14
Average 2005	27.01	9.88	13.77	4.63
Average 2004	22.51	9.00	13.20	0.00
Site 2 Spot 2 Engraving				
Average 2014	45.08	11.00	20.72	1.53
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	
Average 2008	34.87	9.18	19.76	1.18
Average 2007	33.90	9.84	19.67	0.81
Average 2006	34.10	9.11	19.37	1.72
Average 2005	34.02	10.67	20.11	3.30
Average 2004	31.01	10.15	18.84	0.00
Site 2 Spot 2 Background				
Average 2014	28.80	11.02	10.57	1.07
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	
Average 2008	26.94	11.35	12.23	1.85
Average 2007	26.14	10.73	10.68	1.40
Average 2006	26.99	11.49	11.49	2.09
Average 2005	26.42	12.71	13.09	2.89
Average 2004	25.80	10.77	11.04	0.00

Site 2 Spot 3 Engraving				
Average 2014	39.24	13.20	20.18	1.81
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	
Average 2008	28.87	9.67	18.98	7.70
Average 2007	36.55	9.48	19.57	3.78
Average 2006	33.04	10.82	20.02	0.82
Average 2005	33.22	10.56	19.26	5.57
Average 2004	27.68	10.56	18.70	0.00
Site 2 Spot 3 Background				
Average 2014	30.96	13.58	16.97	1.43
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	
Average 2008	21.35	11.54	15.50	6.66
Average 2007	16.10	8.75	12.49	2.70
Average 2006	15.82	10.24	14.72	6.40
Average 2005	21.40	12.57	16.82	2.68
Average 2004	18.82	12.25	16.15	0.00
Site 2 Spot 4 Engraving				
Average 2014	41.88	16.17	22.38	1.73
Average 2013	41.73	14.62	21.63	
Site 2 Spot 4 Background				
Average 2014	36.00	19.32	21.73	2.67
Average 2013	38.12	20.61	22.72	

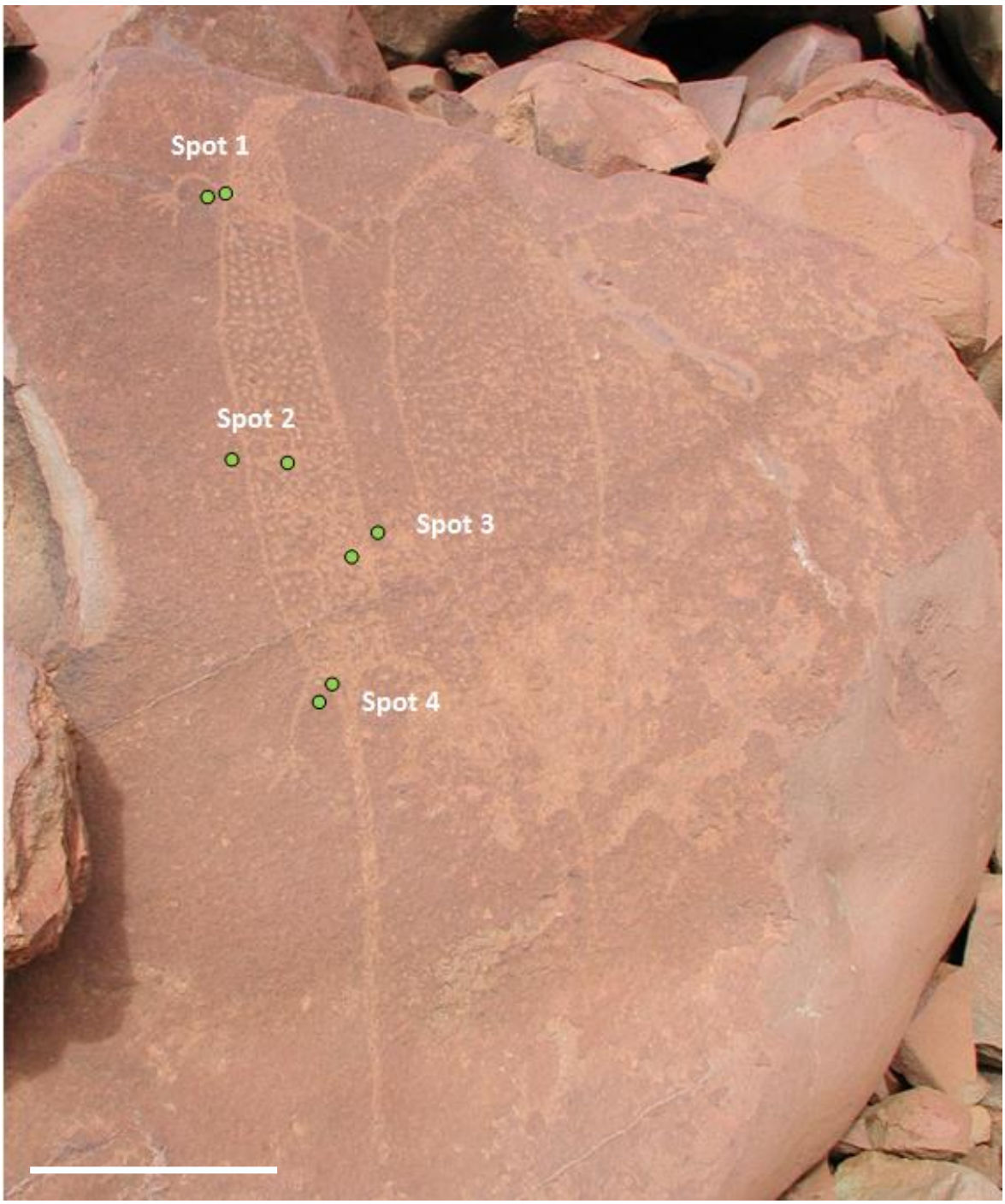


Figure 8: Site 4 – Woodside (White scalebar is 10 cm).

Table 8: Average Colour Measurements for Site 4 – Woodside (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 4 Spot 1 Engraving				
Average 2014	33.85	16.02	18.26	0.90
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	
Average 2008	25.82	13.03	17.71	0.80
Average 2007	25.59	13.62	18.20	0.64
Average 2006	25.36	13.07	17.96	2.44
Average 2005	23.27	14.26	18.34	1.17
Average 2004	22.72	13.84	17.40	0.00
Site 4 Spot 1 Background				
Average 2014	29.15	13.48	13.77	0.92
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	
Average 2008	21.72	10.97	13.27	2.43
Average 2007	19.29	10.98	13.27	1.55
Average 2006	20.71	11.13	13.88	2.03
Average 2005	19.22	12.50	14.02	1.12
Average 2004	20.10	12.06	13.50	0.00
Site 4 Spot 2 Engraving				
Average 2014	32.09	15.96	18.20	1.47
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	
Average 2008	20.38	11.12	15.20	4.42
Average 2007	16.11	10.67	14.17	1.79
Average 2006	14.47	10.11	13.72	2.25
Average 2005	14.55	11.92	15.05	1.26
Average 2004	14.56	10.86	14.38	0.00
Site 4 Spot 2 Background				
Average 2014	31.92	14.07	14.84	0.80
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	
Average 2008	26.04	12.48	15.51	1.96
Average 2007	24.40	12.56	14.44	3.66
Average 2006	27.78	13.47	15.52	1.65
Average 2005	26.27	13.66	16.13	0.35
Average 2004	26.52	13.90	16.11	0.00

Site 4 Spot 3 Engraving				
Average 2014	35.86	16.36	19.54	1.86
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	
Average 2008	24.53	12.51	18.03	5.04
Average 2007	19.69	11.91	16.76	4.84
Average 2006	24.31	12.43	18.13	2.61
Average 2005	23.42	14.49	19.48	1.83
Average 2004	22.41	13.68	18.19	0.00
Site 4 Spot 3 Background				
Average 2014	32.29	14.60	15.74	0.86
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	
Average 2008	25.79	12.62	15.06	2.75
Average 2007	27.83	13.88	16.41	2.02
Average 2006	28.76	13.10	14.79	4.00
Average 2005	25.30	13.83	16.65	1.99
Average 2004	26.33	13.30	15.04	0.00
Site 4 Spot 4 Engraving				
Average 2014	35.80	16.64	20.09	0.77
Average 2013	36.32	16.23	19.70	
Site 4 Spot 4 Background				
Average 2014	32.60	14.41	15.13	0.83
Average 2013	31.86	14.28	15.49	

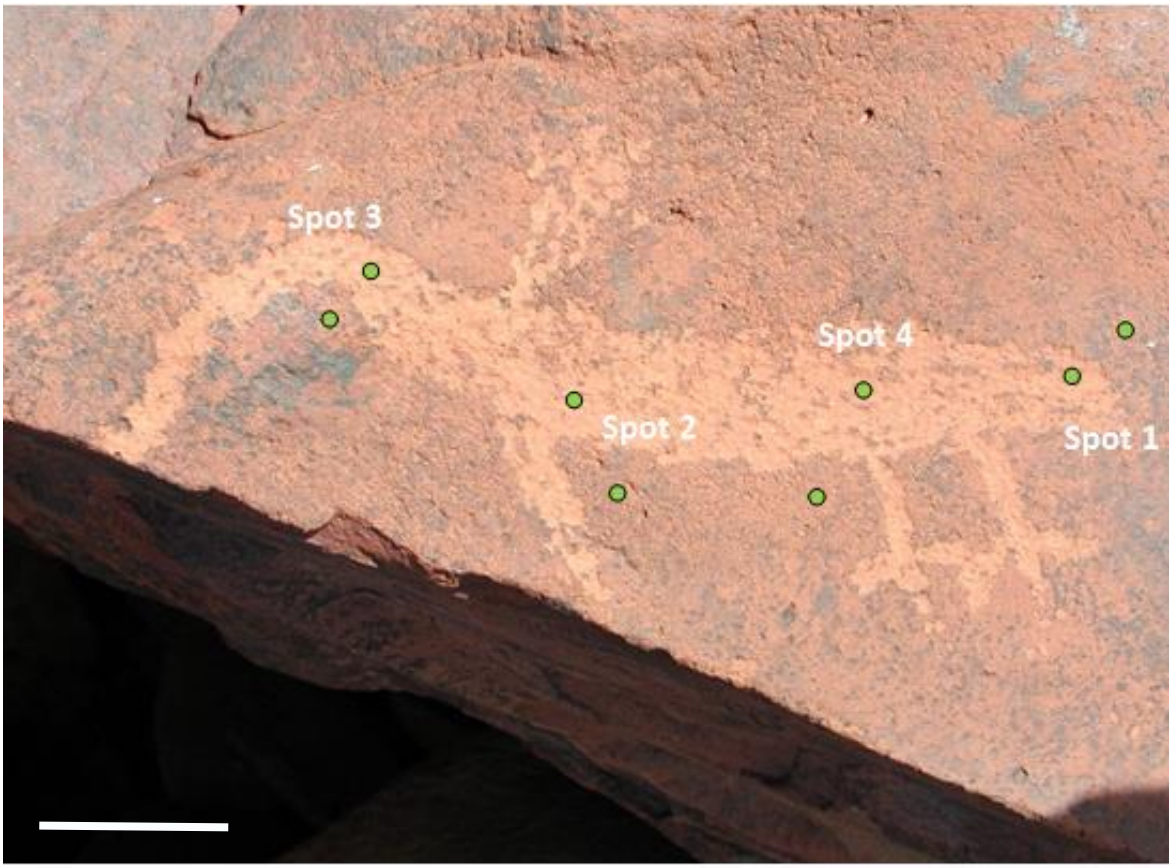


Figure 9: Site 5 – Burrup Road (White scalbar is 10 cm).

Table 9: Average Colour Measurements for Site 5 – Burrup Road (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 5 Spot 1 Engraving				
Average 2014	36.69	16.83	19.25	0.80
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	
Average 2008	26.73	14.82	19.44	1.84
Average 2007	27.80	15.74	20.62	6.52
Average 2006	21.82	13.58	19.19	2.33
Average 2005	22.23	15.50	20.44	4.38
Average 2004	18.90	14.24	17.88	0.00
Site 5 Spot 1 Background				
Average 2014	34.88	14.65	15.33	2.65
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	
Average 2008	27.57	13.69	16.32	2.04
Average 2007	29.04	13.18	15.00	3.64
Average 2006	29.53	10.88	12.22	6.28
Average 2005	27.38	14.45	16.92	5.13
Average 2004	22.94	12.89	14.88	0.00
Site 5 Spot 2 Engraving				
Average 2014	38.59	20.21	23.54	3.98
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	
Average 2008	22.31	13.93	18.02	2.87
Average 2007	19.47	13.54	18.22	8.99
Average 2006	27.52	16.20	21.24	4.86
Average 2005	22.76	16.80	22.02	1.68
Average 2004	22.99	16.78	20.35	0.00
Site 5 Spot 2 Background				
Average 2014	30.28	14.76	15.20	0.94
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	
Average 2008	29.94	13.70	15.58	1.53
Average 2007	29.02	14.63	16.37	2.32
Average 2006	27.19	13.76	15.23	3.61
Average 2005	29.53	15.28	17.53	
Average 2004	No measurements			
Site 5 Spot 3 Engraving				

Average 2014	39.00	18.68	23.08	0.86
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	
Average 2008	34.14	18.58	23.81	3.57
Average 2007	37.22	18.98	25.58	2.97
Average 2006	35.58	17.40	23.67	7.25
Average 2005	28.45	17.51	22.35	9.24
Average 2004	36.88	20.01	25.21	0.00
Site 5 Spot 3 Background				
Average 2014	32.62	11.61	12.22	1.01
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	
Average 2008	21.32	11.77	14.06	7.48
Average 2007	16.96	7.26	9.99	17.28
Average 2006	32.64	13.27	14.07	6.72
Average 2005	26.14	14.02	15.60	1.00
Average 2004	25.31	13.75	15.11	0.00
Site 5 Spot 4 Engraving				
Average 2014	37.27	19.30	22.02	0.49
Average 2013	37.69	19.24	22.26	
Site 5 Spot 4 Background				
Average 2014	32.93	15.58	16.40	1.13
Average 2013	32.44	14.87	15.68	

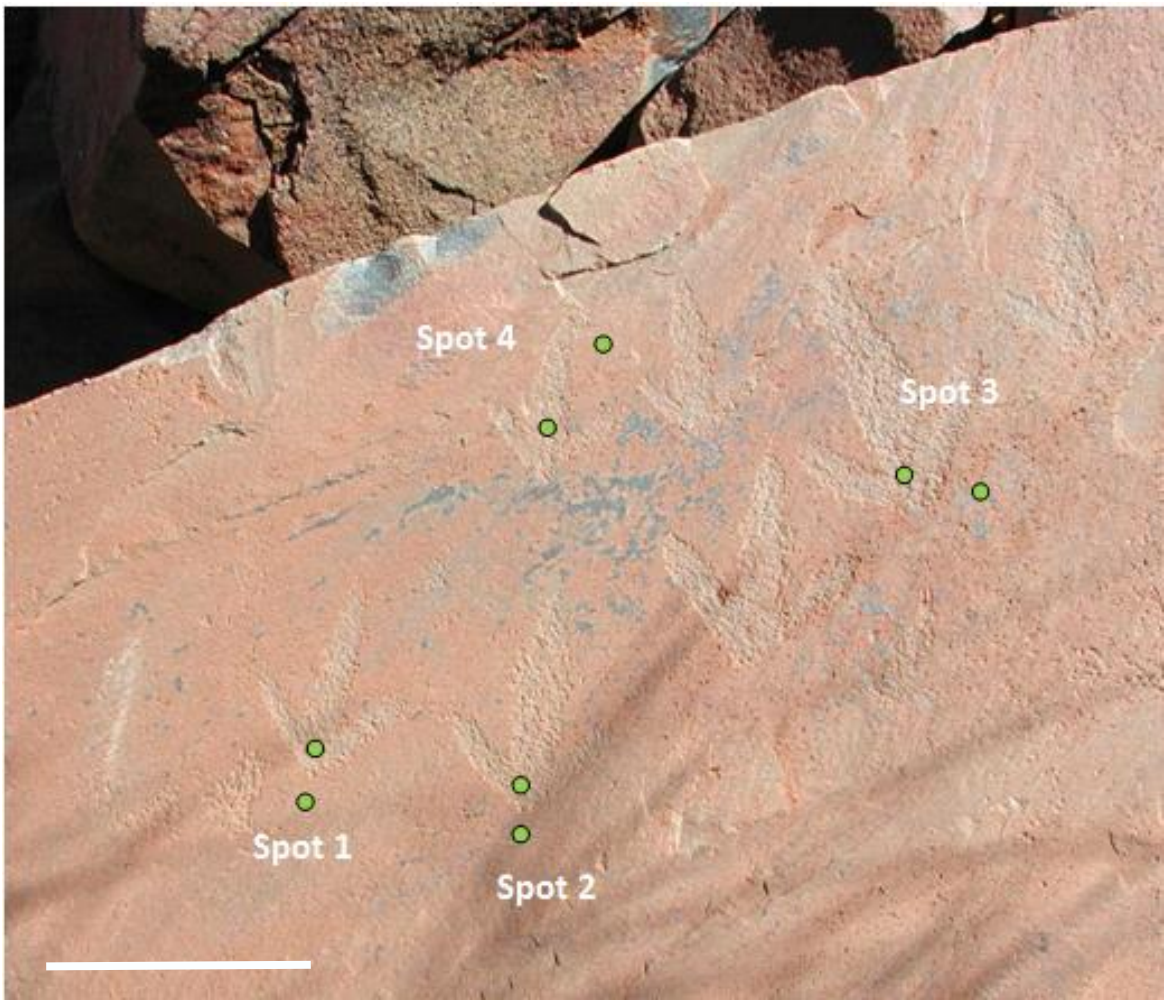


Figure 10: Site 6 – Water Tanks (White scalebar is 10 cm).

Table 10: Average Colour Measurements for Site 6 – Water Tanks (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 6 Spot 1 Engraving				
Average 2014	40.29	10.89	16.68	1.47
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	
Average 2008	34.15	9.73	16.80	0.39
Average 2007	34.37	9.96	17.03	2.87
Average 2006	36.83	11.28	17.69	1.28
Average 2005	35.71	11.56	18.24	5.56
Average 2004	30.20	12.27	18.25	0.00
Site 6 Spot 1 Background				
Average 2014	39.47	12.75	17.08	0.25
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	
Average 2008	35.94	11.71	17.55	2.16
Average 2007	36.95	13.32	18.57	0.45
Average 2006	36.89	13.76	18.51	3.02
Average 2005	34.04	12.80	18.20	2.85
Average 2004	36.87	13.22	18.25	0.00
Site 6 Spot 2 Engraving				
Average 2014	39.24	11.96	17.10	0.90
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	
Average 2008	34.14	9.62	16.25	1.14
Average 2007	33.69	10.43	16.91	0.72
Average 2006	33.47	11.10	16.81	2.28
Average 2005	31.25	11.24	17.31	2.53
Average 2004	33.73	11.01	16.87	0.00
Site 6 Spot 2 Background				
Average 2014	37.08	12.16	15.21	2.14
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	
Average 2008	36.20	12.05	16.95	1.27
Average 2007	35.20	11.95	16.18	0.78
Average 2006	35.90	11.98	15.83	1.09
Average 2005	34.86	11.90	16.12	1.72
Average 2004	35.27	13.08	17.31	0.00
Site 6 Spot 3 Engraving				

Average 2014	38.18	11.36	15.93	0.86
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	
Average 2008	35.59	9.61	15.75	1.51
Average 2007	34.18	10.03	16.08	0.86
Average 2006	33.49	10.26	15.62	2.56
Average 2005	34.97	11.45	17.34	1.54
Average 2004	36.39	11.09	16.88	0.00
Site 6 Spot 3 Background				
Average 2014	38.72	11.79	15.83	1.62
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	
Average 2008	36.53	12.29	17.21	2.03
Average 2007	35.56	13.65	18.37	3.81
Average 2006	36.03	11.19	15.51	3.31
Average 2005	35.59	13.40	17.93	1.45
Average 2004	36.88	12.77	17.69	0.00
Site 6 Spot 4 Engraving				
Average 2014	39.47	11.26	16.42	1.68
Average 2013	41.12	10.97	16.58	
Site 6 Spot 4 Background				
Average 2014	38.94	13.10	16.68	0.68
Average 2013	39.43	13.37	17.05	

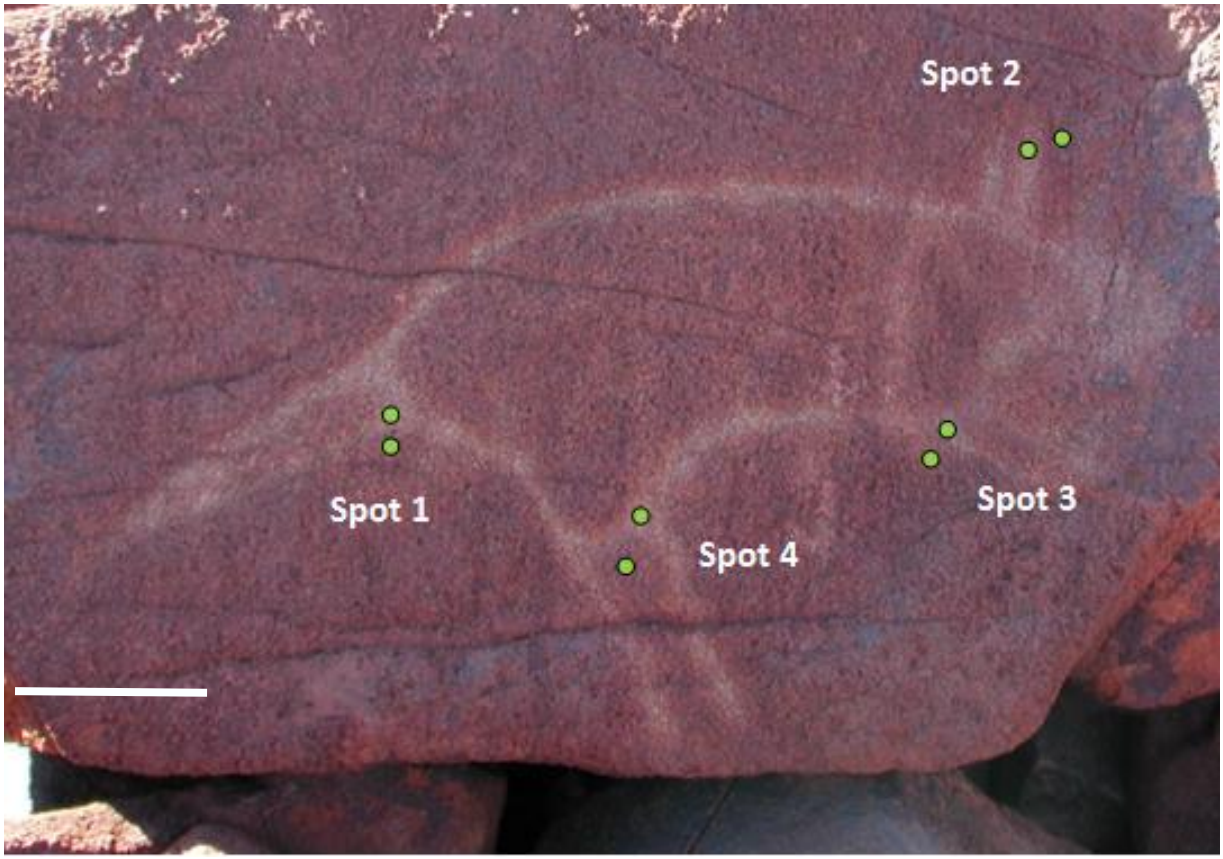


Figure 11: Site 7 – Deep Gorge (White scalebar is 25 cm).

Table 11: Average Colour Measurements for Site 7 – Deep Gorge (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 7 Spot 1 Engraving				
Average 2014	37.24	14.40	18.37	3.10
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	
Average 2008	26.36	12.19	18.55	12.38
Average 2007	16.41	8.35	12.26	3.56
Average 2006	12.89	8.47	11.74	17.84
Average 2005	28.13	14.49	18.79	23.71
Average 2004	7.10	8.55	9.60	0.00
Site 7 Spot 1 Background				
Average 2014	31.05	15.58	16.21	3.14
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	
Average 2008	16.18	9.78	13.47	1.42
Average 2007	16.65	11.04	13.94	3.35
Average 2006	19.85	12.01	14.06	3.00
Average 2005	17.04	12.99	13.74	1.41
Average 2004	17.08	13.26	15.13	0.00
Site 7 Spot 2 Engraving				
Average 2014	31.22	15.24	16.45	1.95
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	
Average 2008	11.93	10.08	11.82	1.14
Average 2007	12.71	10.43	12.58	10.65
Average 2006	5.50	5.66	6.36	6.80
Average 2005	11.02	8.56	9.07	8.75
Average 2004	3.51	6.44	5.12	0.00
Site 7 Spot 2 Background				
Average 2014	27.38	12.73	12.27	0.91
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	
Average 2008	19.81	10.19	12.97	3.72
Average 2007	16.62	12.07	13.37	1.25
Average 2006	17.85	11.89	13.48	3.49
Average 2005	14.56	12.93	12.97	10.14
Average 2004	24.65	12.01	13.36	0.00
Site 7 Spot 3 Engraving				

Average 2014	32.53	14.04	16.07	1.60
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	
Average 2008	3.00	1.90	3.26	0.51
Average 2007	2.62	2.16	3.03	15.06
Average 2006	12.77	9.35	11.52	15.86
Average 2005	2.00	2.42	2.17	
Average 2004	No measurements			
Site 7 Spot 3 Background				
Average 2014	30.38	14.52	15.19	0.95
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	
Average 2008	12.77	7.70	10.24	3.50
Average 2007	9.63	7.07	8.84	11.62
Average 2006	19.22	11.73	13.46	8.59
Average 2005	11.27	10.21	10.58	8.87
Average 2004	18.44	13.30	14.79	0.00
Site 7 Spot 4 Engraving				
Average 2014	35.81	14.81	18.28	2.47
Average 2013	38.03	15.29	19.25	
Site 7 Spot 4 Background				
Average 2014	27.38	12.07	12.65	3.27
Average 2013	30.26	12.88	13.97	

Figure 12: Site 8 – King Bay South (Colour chart on rock is 10 cm).

Table 12: Average Colour Measurements for Site 8 – King Bay South (2004 – 2014).
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 8 Spot 1 Engraving				
Average 2014	35.05	14.20	14.99	1.01
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	
Average 2008	26.57	11.35	14.83	2.79
Average 2007	29.05	12.58	14.52	2.18
Average 2006	28.28	13.43	16.38	2.53
Average 2005	25.77	13.71	16.33	5.59
Average 2004	31.26	14.75	16.12	0.00
Site 8 Spot 1 Background				
Average 2014	32.91	12.17	11.76	0.62
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	
Average 2008	29.92	11.55	12.36	0.88
Average 2007	29.10	11.46	12.04	2.78
Average 2006	26.48	10.55	12.13	2.54
Average 2005	27.10	12.56	13.54	1.31
Average 2004	27.41	11.91	12.46	0.00
Site 8 Spot 2 Engraved				
Average 2014	35.99	14.51	14.84	1.26
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	
Average 2008	21.89	10.90	13.95	3.44
Average 2007	24.74	12.68	14.67	7.81
Average 2006	17.80	9.77	12.59	10.32
Average 2005	27.28	13.24	14.74	6.39
Average 2004	20.94	12.58	14.34	0.00
Site 8 Spot 2 Background				
Average 2014	31.63	11.39	11.14	1.25
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	
Average 2008	27.22	10.60	12.42	1.03
Average 2007	26.40	11.17	12.17	1.13
Average 2006	25.81	10.27	11.83	2.57
Average 2005	23.69	11.53	12.56	2.21
Average 2004	25.87	11.69	12.18	0.00
Site 8 Spot 3 Engraved				

Average 2014	34.09	15.74	19.36	0.79
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	
Average 2008	21.31	11.85	17.11	0.66
Average 2007	20.69	11.97	16.92	2.31
Average 2006	22.85	12.46	17.59	6.21
Average 2005	16.79	12.23	16.24	5.26
Average 2004	21.72	13.40	17.68	0.00
Site 8 Spot 3 Background				
Average 2014	30.14	13.48	14.64	0.60
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	
Average 2008	26.73	13.08	16.21	5.03
Average 2007	22.36	11.92	14.01	1.47
Average 2006	22.57	12.53	15.33	1.62
Average 2005	24.03	13.19	15.50	3.19
Average 2004	26.98	13.09	14.27	0.00
Site 8 Spot 4 Engraved				
Average 2014	33.65	15.66	18.53	1.08
Average 2013	34.11	15.20	17.67	
Site 8 Spot 4 Background				
Average 2014	30.89	13.15	14.35	0.29
Average 2013	30.68	12.94	14.32	

Figure 13: Site 21 – Yara West (Colour chart on rock is 10 cm).

Table 13: Average Colour Measurements for Site 21- Yara West (2014 Feb - July).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 21 Spot 1 Engraving				
Average 2014 (July)	39.07	17.29	22.14	1.59
Average 2014 (February)	38.04	16.35	21.38	0.00
Site 21 Spot 1 Background				
Average 2014 (July)	32.85	14.03	13.75	1.37
Average 2014 (February)	31.59	13.76	13.26	0.00
Site 21 Spot 2 Engraving				
Average 2014 (July)	37.55	15.55	20.36	1.52
Average 2014 (February)	36.08	15.33	20.04	0.00
Site 21 Spot 2 Background				
Average 2014 (July)	34.94	14.40	16.13	1.19
Average 2014 (February)	33.77	14.19	16.23	0.00
Site 21 Spot 3 Engraving				
Average 2014 (July)	38.54	17.96	22.82	2.56
Average 2014 (February)	38.57	16.01	21.17	0.00
Site 21 Spot 3 Background				
Average 2014 (July)	31.95	14.23	15.22	0.63
Average 2014 (February)	31.56	13.99	15.64	0.00
Site 21 Spot 4 Engraving				
Average 2014 (July)	38.71	15.71	20.23	2.80
Average 2014 (February)	37.41	17.28	22.16	0.00
Site 21 Spot 4 Background				
Average 2014 (July)	32.89	13.69	14.83	2.16
Average 2014 (February)	31.53	12.39	13.77	0.00

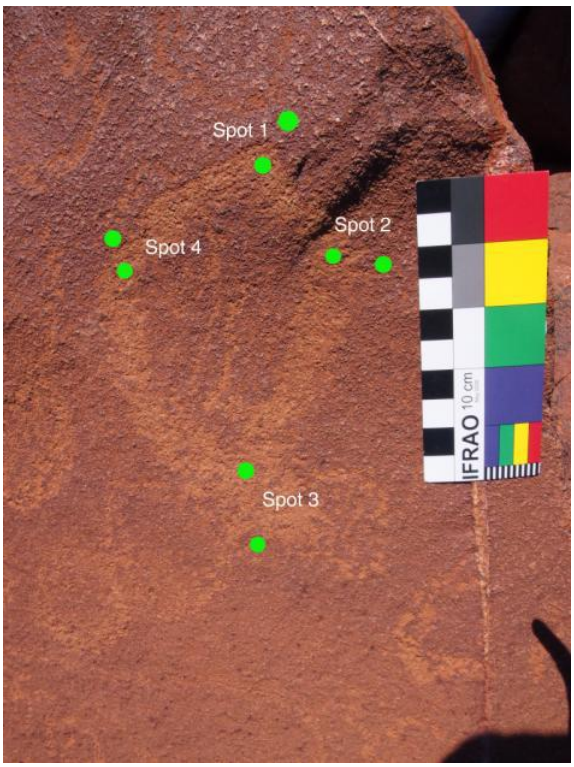


Figure 14: Site 22 – Yara North East (Colour chart on rock is 10 cm).

Table 14: Average Colour Measurements for Site 22 – Yara North East (2014 Feb - July).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 22 Spot 1 Engraving				
Average 2014 (July)	39.12	13.54	19.02	2.91
Average 2014 (February)	36.82	13.54	17.23	0.00
Site 22 Spot 1 Background				
Average 2014 (July)	34.08	12.21	12.63	0.39
Average 2014 (February)	33.80	12.11	12.37	0.00
Site 22 Spot 2 Engraving				
Average 2014 (July)	37.08	14.33	18.65	2.60
Average 2014 (February)	35.15	13.64	17.04	0.00
Site 22 Spot 2 Background				
Average 2014 (July)	33.85	12.72	13.90	1.54
Average 2014 (February)	32.32	12.52	14.00	0.00
Site 22Spot 3 Engraving				
Average 2014 (July)	38.34	14.49	19.51	1.71
Average 2014 (February)	37.11	14.41	18.33	0.00
Site 22 Spot 3 Background				
Average 2014 (July)	33.71	12.53	13.82	0.53
Average 2014 (February)	34.06	12.75	14.15	0.00
Site 22 Spot 4 Engraving				
Average 2014 (July)	36.12	13.99	17.71	1.43
Average 2014 (February)	37.32	14.11	18.48	0.00
Site 22 Spot 4 Background				
Average 2014 (July)	33.96	12.41	13.31	1.07
Average 2014 (February)	33.63	11.92	12.42	0.00

Figure 15: Site 23 – Yara East (Colour chart on rock is 10 cm).

Table 15: Average Colour Measurements for Site 23 - Yara East (2014 Feb - July).

Sample	Colour scale L*	a*	b*	Colour difference* ΔE (change from previous year)
Site 23 Spot 1 Engraving				
Average 2014 (July)	36.71	9.61	16.09	1.72
Average 2014 (February)	38.39	9.59	16.49	0.00
Site 23 Spot 1 Background				
Average 2014 (July)	34.54	11.54	15.42	1.00
Average 2014 (February)	35.16	12.08	16.00	0.00
Site 23 Spot 2 Engraving				
Average 2014 (July)	32.86	11.53	18.35	2.93
Average 2014 (February)	35.36	12.90	19.05	0.00
Site 23 Spot 2 Background				
Average 2014 (July)	37.26	14.00	19.05	0.43
Average 2014 (February)	36.93	14.28	19.04	0.00
Site 23 Spot 3 Engraving				
Average 2014 (July)	37.71	10.69	17.28	0.48
Average 2014 (February)	38.17	10.72	17.42	0.00
Site 23 Spot 3 Background				
Average 2014 (July)	31.86	14.14	16.13	0.70
Average 2014 (February)	31.70	13.65	15.65	0.00
Site 23 Spot 4 Engraving				
Average 2014 (July)	37.82	10.65	17.36	1.47
Average 2014 (February)	36.39	10.94	17.20	0.00
Site 23 Spot 4 Background				
Average 2014 (July)	32.12	7.46	10.56	3.24
Average 2014 (February)	31.61	9.92	12.60	0.00

The averaged colour change for each site is presented in Table 17, which is an overall average for each of the six spots measured on a petroglyph, with data from the additional 4th engraving and background spot included in 2014 results[3]. The colour change for both the Southern and Northern sites for the period are reasonably consistent over the measurement period, At any given time interval,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.

Table 16: Averaged colour change for each site.
Note: KM measurements in red. No comparison calculated for 2008-09 due to change of instrument.
***Comparison of 2004 with 2014 used 2004 BYK data converted to be comparable with KM data.**

Site	Averaged site-specific colour change										
	ΔE 13–14	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	ΔE 04–14*
4	**0.93**	0.79	1.50	1.79	2.70		2.90	2.42	2.34	1.29	11.04
5	**1.48**	2.12	1.23	1.68	1.94		3.22	6.95	4.98	4.29	13.62
6	**1.20**	0.89	1.04	0.53	2.61		1.42	1.58	2.23	2.61	14.06
7	**2.17**	1.80	2.46	1.04	1.76		3.78	7.58	9.00	10.58	9.48
8	**0.86**	0.88	1.54	1.30	3.60		2.30	2.94	4.09	3.99	12.24
21	**1.73**										
22	**1.35**										
23	**1.50**										
Overall southern sites average	1.40	1.30	1.55	1.27	2.51		2.72	4.30	4.53	4.55	12.09
1	**1.87**	2.15	1.60	1.37	1.16		4.06	4.50	3.43	2.88	14.01
2	**1.82**	1.03	1.59	1.31	2.30		4.01	2.38	2.88	3.56	13.02
Overall northern sites average	1.84	1.59	1.59	1.34	1.73		4.05	3.44	3.16	3.22	13.52

The eleven 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 2004–14, which indicates the colour change over the eleven year interval from 2004 to 2014, 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 2004–14 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

[3] Spot 4 has not been included prior to 2014 as initial measurements were taken in 2013, therefore no colour change for previous years could be calculated.

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 9) 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 10), however, did not consistently record the lowest colour change values so measurement repeatability is therefore dependent on more than just surface roughness.

The 2014 data for sites 21,22 and 23 all show average colour change values that are smaller than those of the northern control sites, and are comparable to Sites 5, 6 and 7 which form part of the monitoring for the Yara Pilbara Nitrates Pty Ltd (YPNPL) Technical Ammonium Nitrate Production Facility Project.

3.3.2 BACKGROUND – ENGRAVING COLOUR DIFFERENCE

The colour difference between the background and petroglyph for each spot is presented in Table 18 and are plotted in

Figure 16 – 25.

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 (Figures 16-22[4]).

[4] Trend line has not been included for spot 4 as each site only has 2 data points.

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 20 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, the colour difference has stabilised over time, with this trend also evident at Site 2. For the southern sites, the measurements at Site seven are variable; consistent with the roughness of the surface, but a linear fit of more recent data indicates a decreasing colour difference trend for spots 1 and 3, and a slightly increasing trend for spot 2. Sites 4, 5, and 8 all exhibit consistent colour differences, with some evidence of a slight increasing trend at some spots. Site 5 Spot 1 has what appears to be an anomalously low 2013 value, however this value is comparable with 2014 measurements. As shown in the plots presented in

Figure 16 - 22 the trends evident in relation to contrast between the background and engraved image at the southern test sites were not observed to be markedly different from those observed in the northern control sites data. Figures 23 – 25 plot the colour difference between background and engraving for the 3 new sites included for monitoring as part of the Yara Pilbara Nitrates Pty Ltd (YPNPL) Technical Ammonium Nitrate Production Facility Project. While some spots show a decreasing trend in colour difference (Site 21, Spot 4; Site 22 Spot 4; Site 23, Spot Spot 1 and 3), this is most likely due to difficulty associated with precise replication of analysis location as the contrast of the petroglyphs with the rock background is low due to the age of the rock art.

Table 17: Colour difference between background and petroglyph
Note: KM measurements in red.

Spot 1	Site 1	Site 2	Site 4	Site 5	Site 6	Site 7	Site 8	Site 21	Site 22	Site 23
Average 2014	**10.9**	**6.5**	**7.0**	**4.8**	**2.1**	**6.7**	**4.4**	**10.9**	**8.2**	**3.0**
Average 2013	12.4	10.0	7.1	2.2	2.0	5.5	5.1	10.7	5.9	4.1
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	12.7	5.5	6.4	3.4	2.8	11.6	4.2			
Average 2007	12.3	6.9	8.4	6.3	4.5	3.2	2.7			
Average 2006	13.8	9.3	6.5	10.7	2.6	8.2	5.4			
Average 2005	13.8	7.6	6.2	6.3	2.1	12.3	3.3			
Average 2004	16.0	9.8	5.0	5.2	6.7	12.3	6.0			
Spot 2										
Average 2014	**12.0**	**19.2**	**3.9**	**13.0**	**2.9**	**6.2**	**6.5**	**5.1**	**6.0**	**5.1**
Average 2013	10.7	18.7	3.4	9.5	2.0	6.5	6.4	4.6	4.3	2.1
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	11.7	11.1	5.8	8.0	3.3	8.0	5.6			
Average 2007	9.5	11.9	8.5	9.8	2.3	4.3	3.4			
Average 2006	20.6	10.9	13.8	6.5	2.8	15.6	8.1			
Average 2005	13.2	10.5	11.9	8.3	3.9	6.8	4.5			
Average 2004	19.4	9.4	12.5	0.0	2.6	23.4	5.5			
Spot 3										
Average 2014	**11.3**	**8.9**	**5.5**	**14.4**	**0.7**	**2.4**	**6.6**	**10.7**	**7.6**	**6.9**
Average 2013	11.4	9.8	6.7	13.2	1.5	3.3	5.8	9.2	5.4	7.3
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	19.7	8.5	3.2	17.5	3.2	13.3	5.6			
Average 2007	9.9	21.7	8.4	28.1	4.5	10.3	3.4			
Average 2006	12.8	18.0	5.6	10.9	2.7	7.1	2.3			
Average 2005	16.3	12.2	3.5	7.9	2.1	14.7	7.3			
Average 2004	17.7	9.4	5.0	16.6	1.9	0.0	6.3			
Spot 4										
Average 2014	**7.6**	**6.7**	**6.3**	**8.0**	**1.9**	**10.5**	**5.6**	**8.2**	**5.2**	**9.4**
Average 2013	12.1	7.1	6.4	9.4	3.0	9.7	5.3	11.4	7.4	6.7

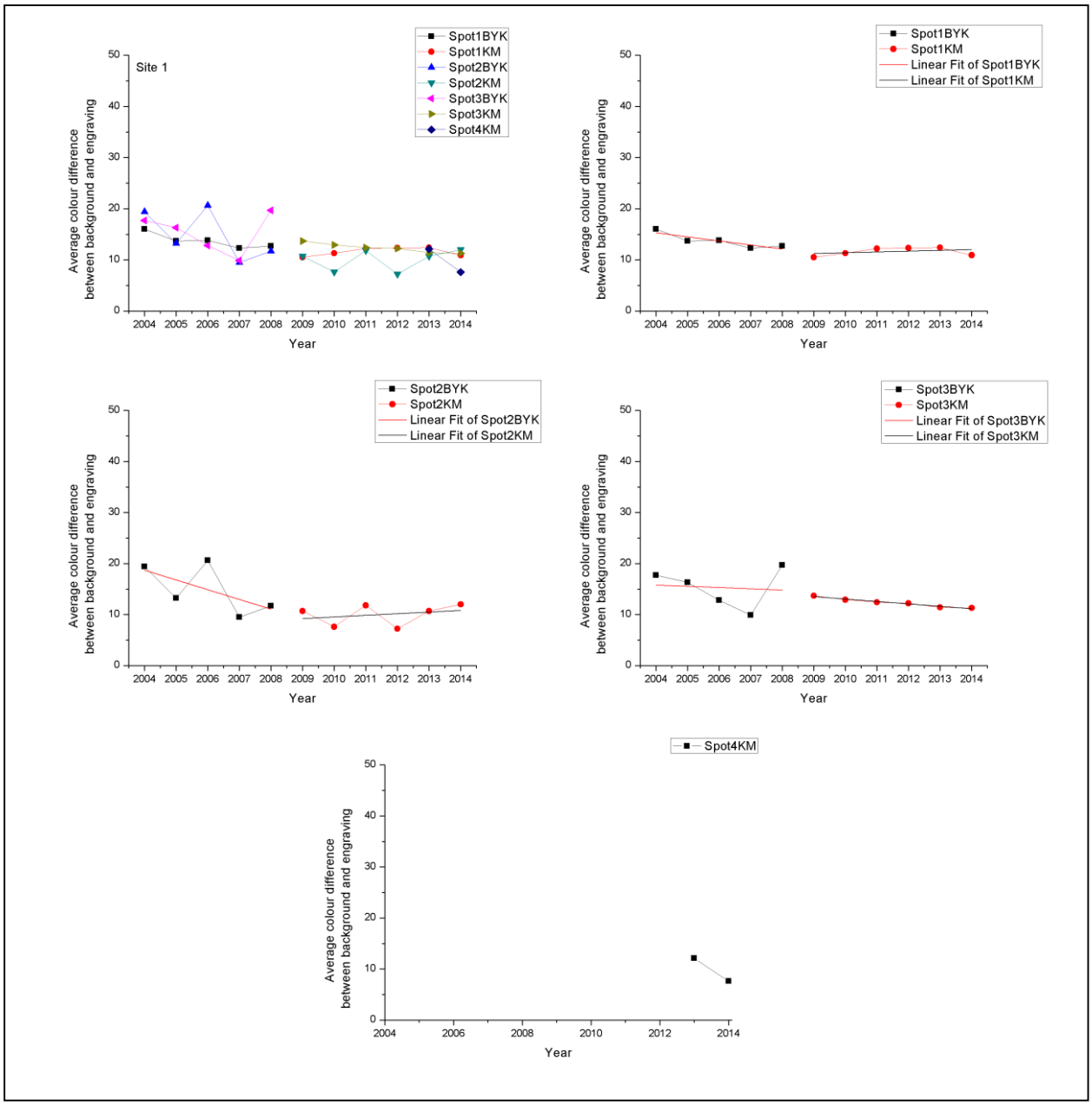


Figure 16: Colour differences between engraving and background for each spot examined at Site 1 – Dolphin Island.

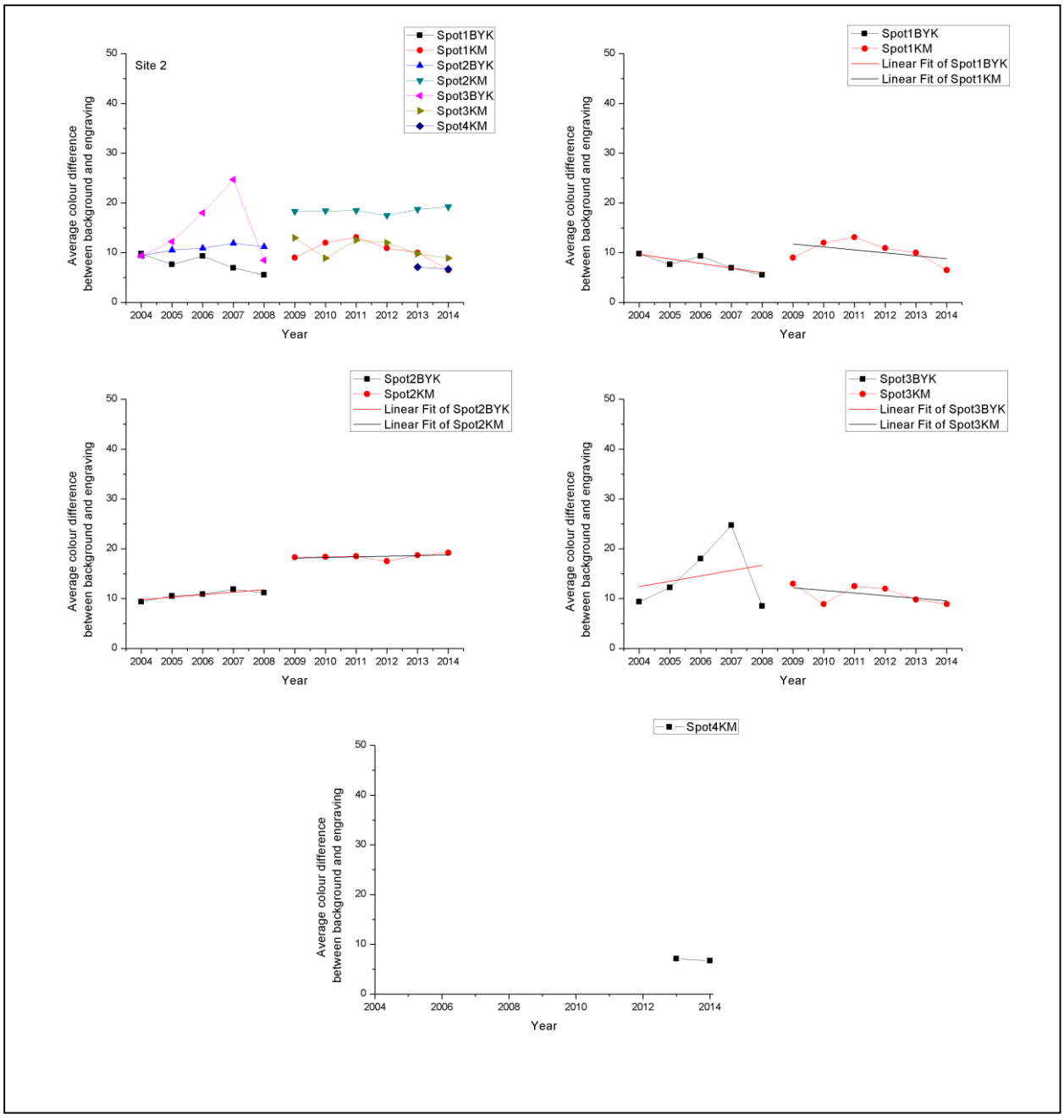


Figure 17: Colour differences between engraving and background for each spot examined at Site 2 – Gidley Island.

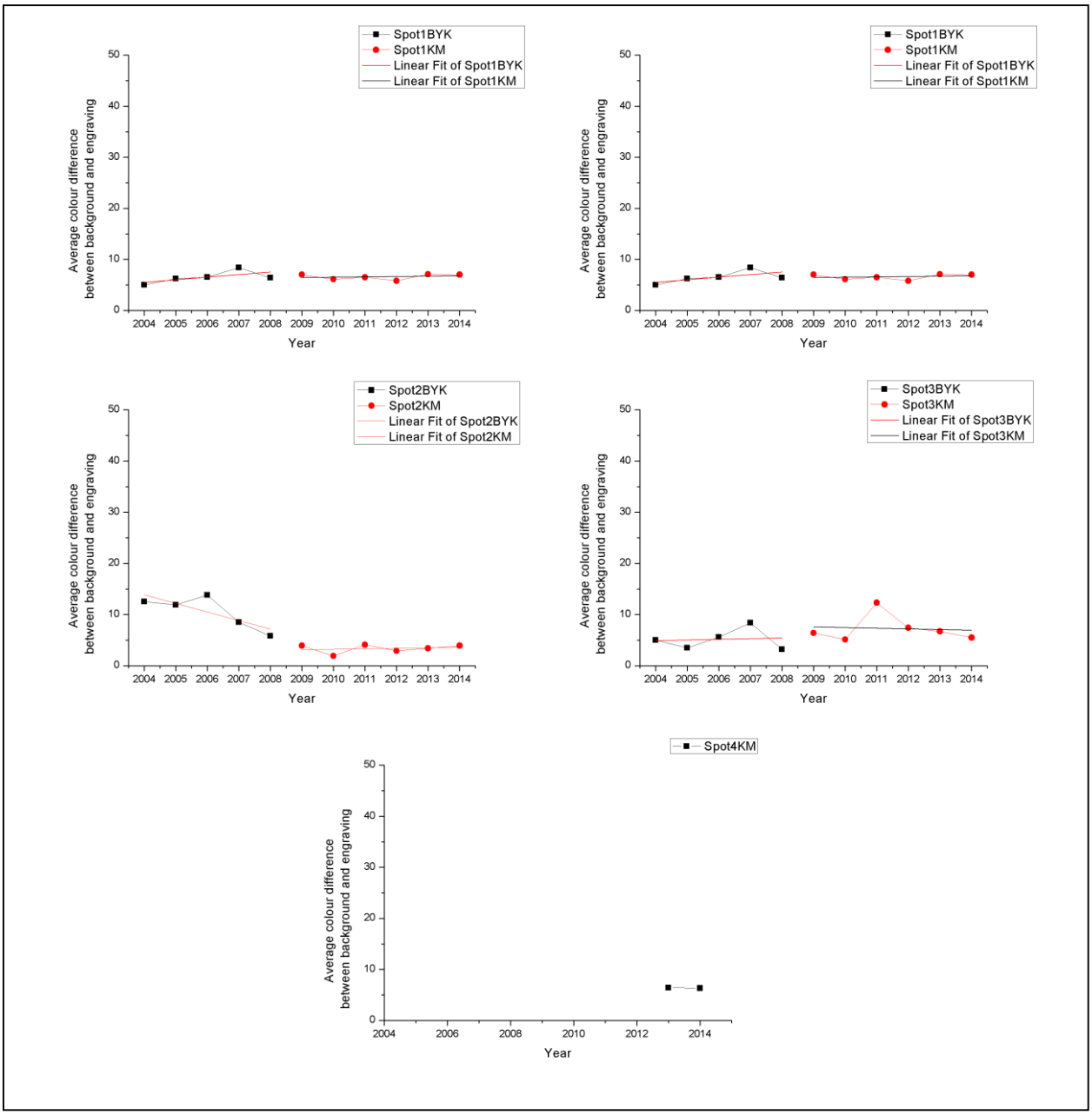


Figure 18: Colour differences between engraving and background for each spot examined at Site 4 – Woodside.

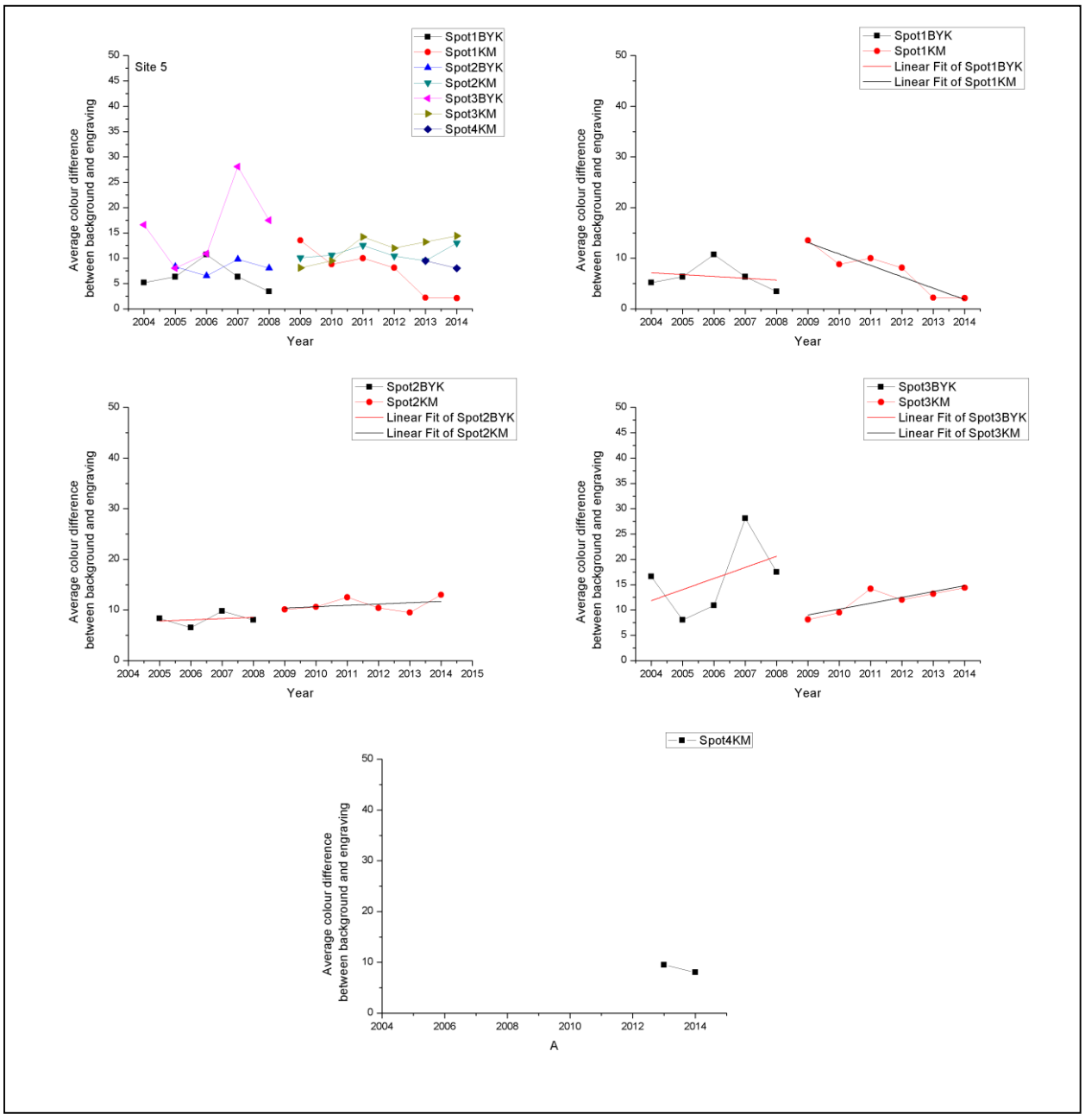


Figure 19: Colour differences between engraving and background for each spot examined at Site 5 – Burrup Road.

Note: Site 5 spot 3 is believed to exhibit high variance in single years due to irregular measurements.

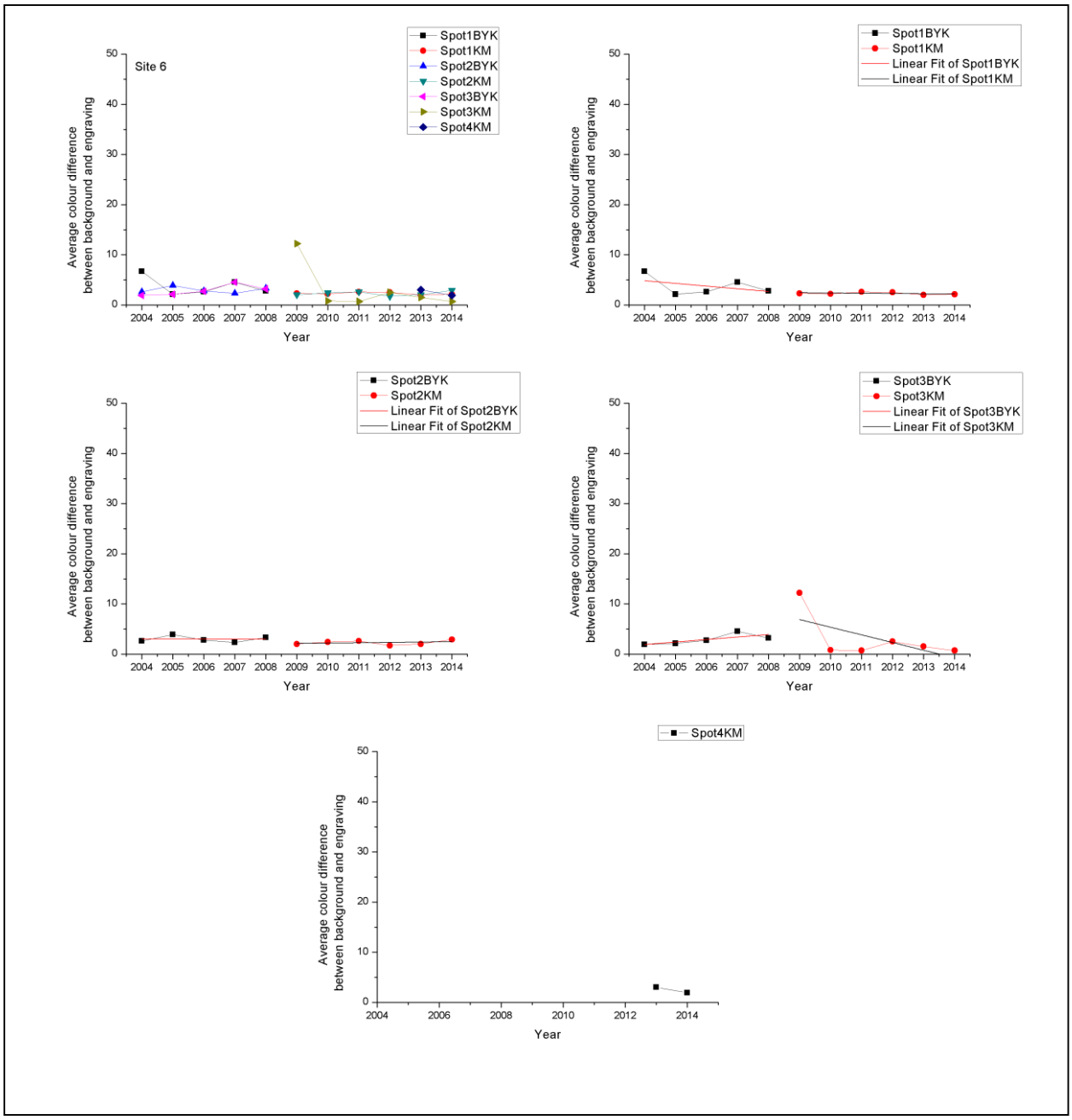


Figure 20: Colour differences between engraving and background for each spot examined at Site 6 – Water Tanks.

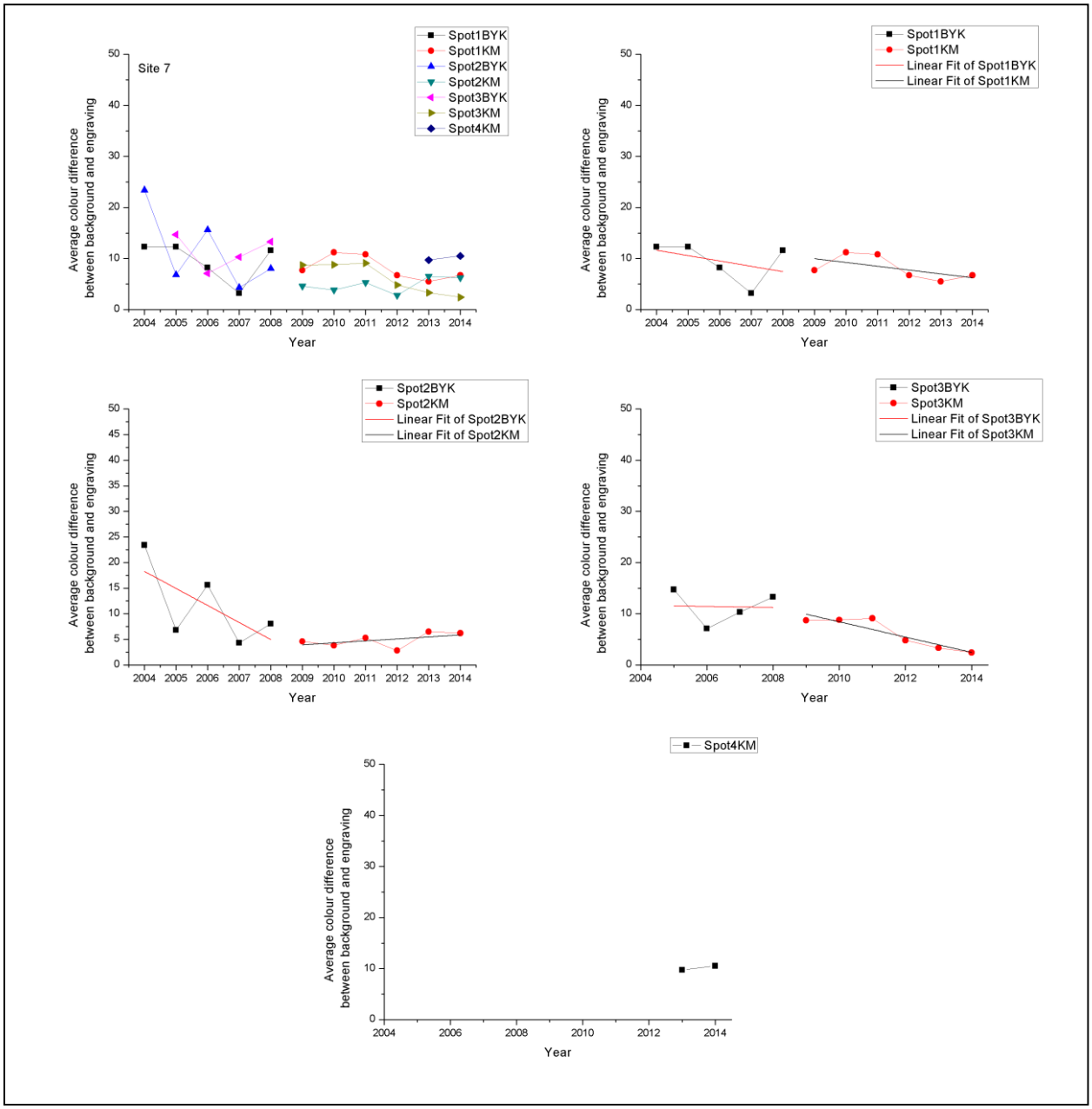


Figure 21: Colour differences between engraving and background for each spot examined at Site 7 – Deep Gorge. Note: Site 7 spot 2 is believed to exhibit high variance in single years due to irregular measurements.

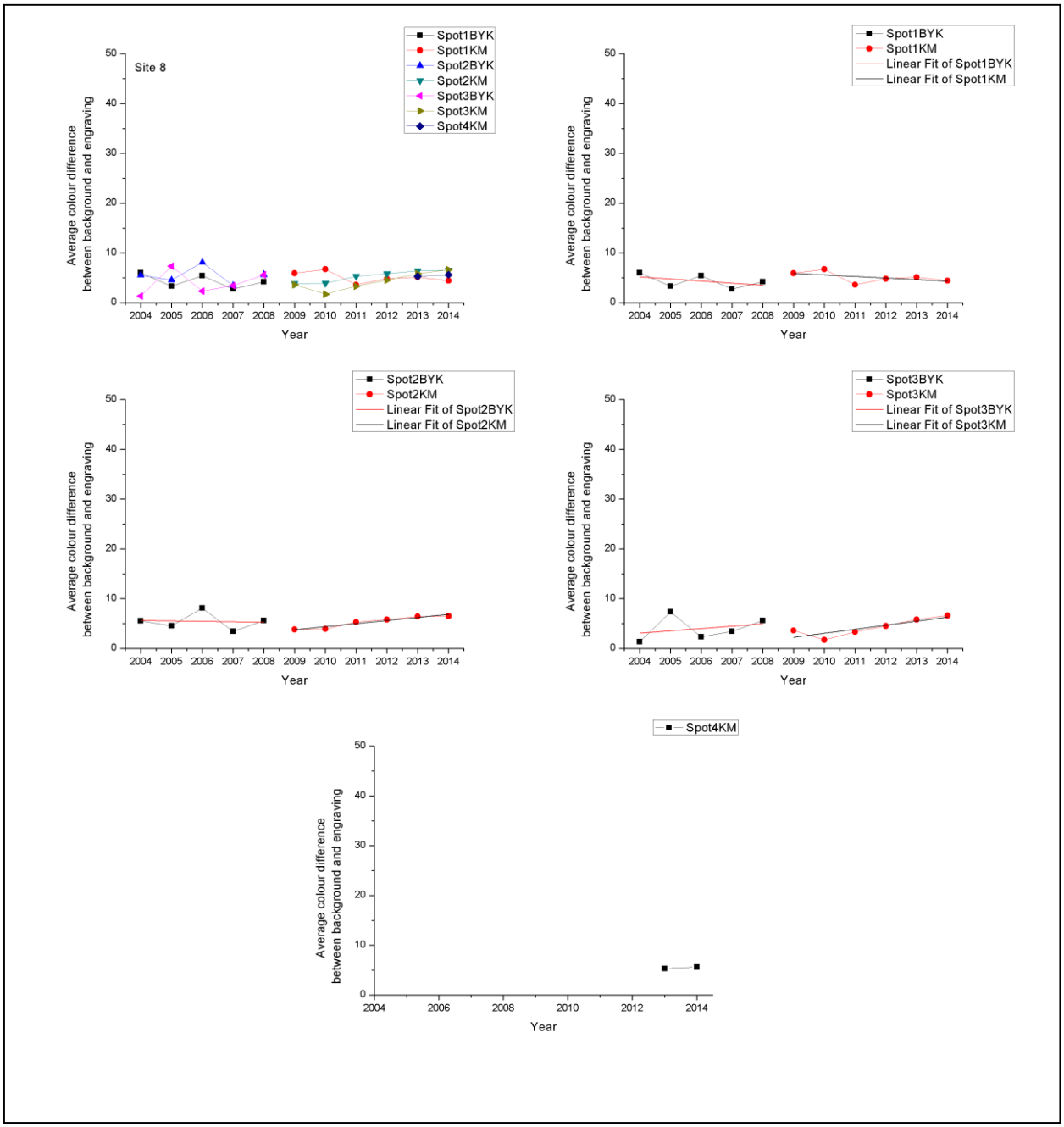


Figure 22: Colour differences between engraving and background for each spot examined at Site 8 – King Bay South.

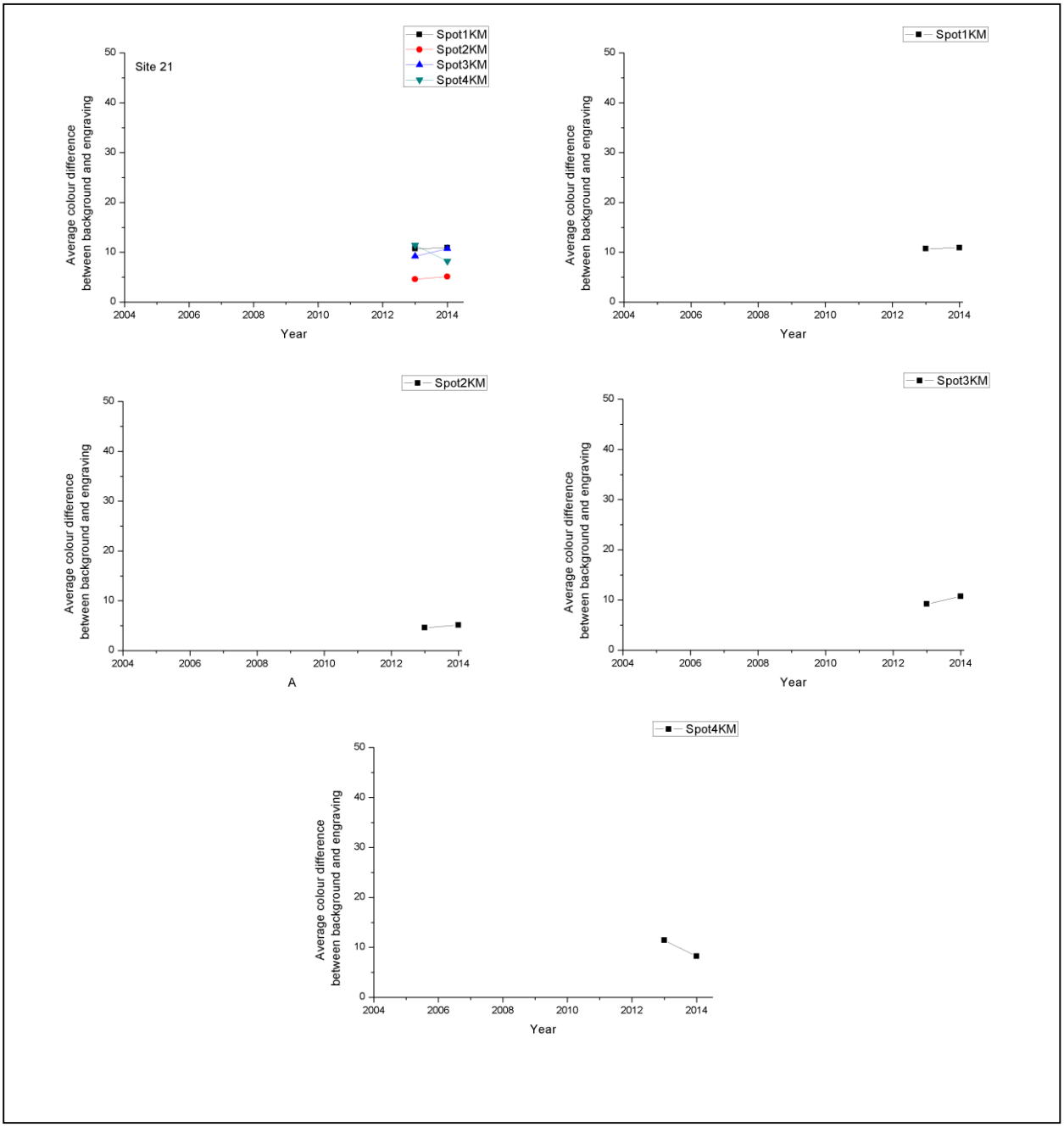


Figure 23: Colour differences between engraving and background for each spot examined at Site 21 – Yara West.

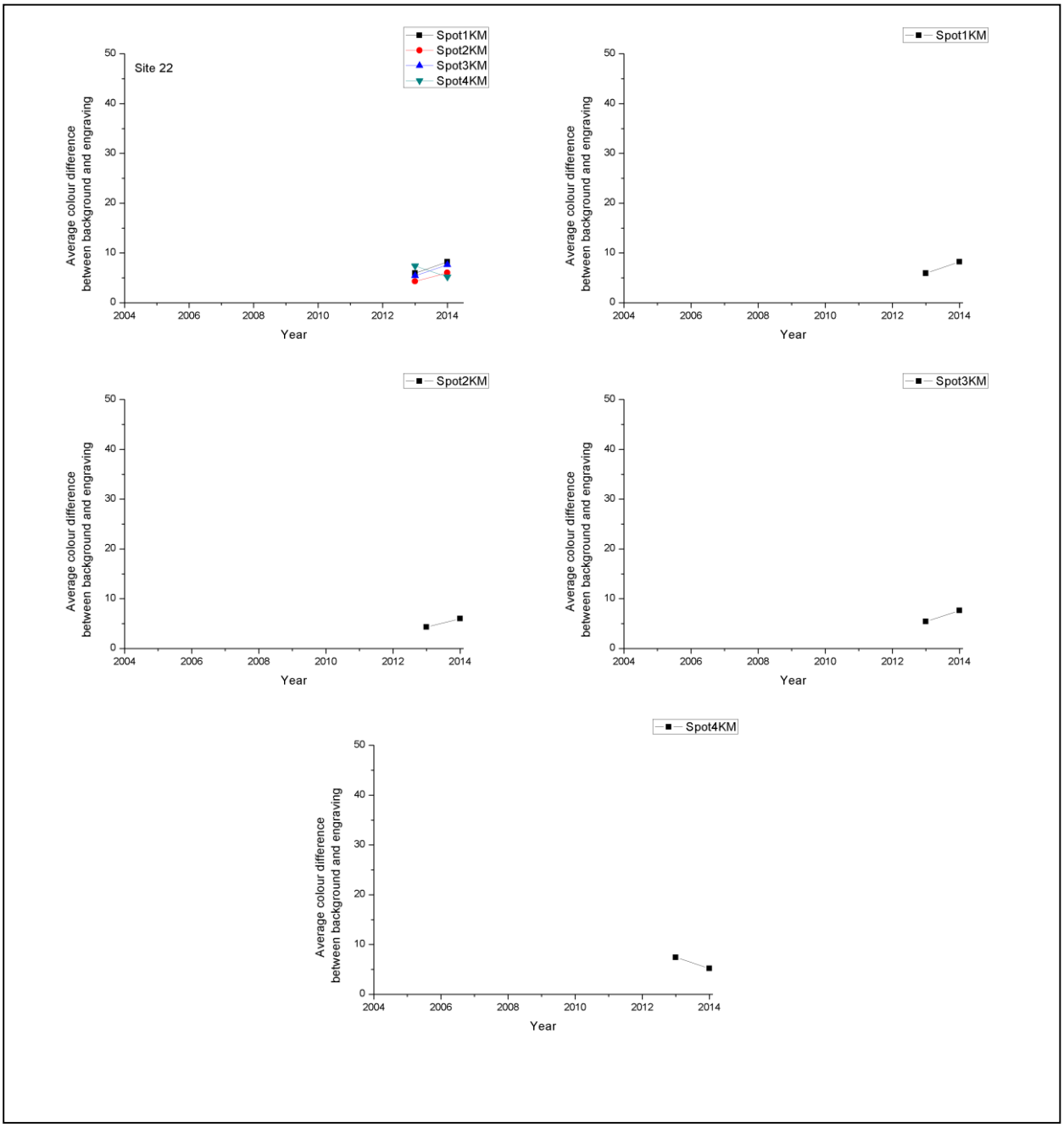


Figure 24: Colour differences between engraving and background for each spot examined at Site 22 – Yara North East.

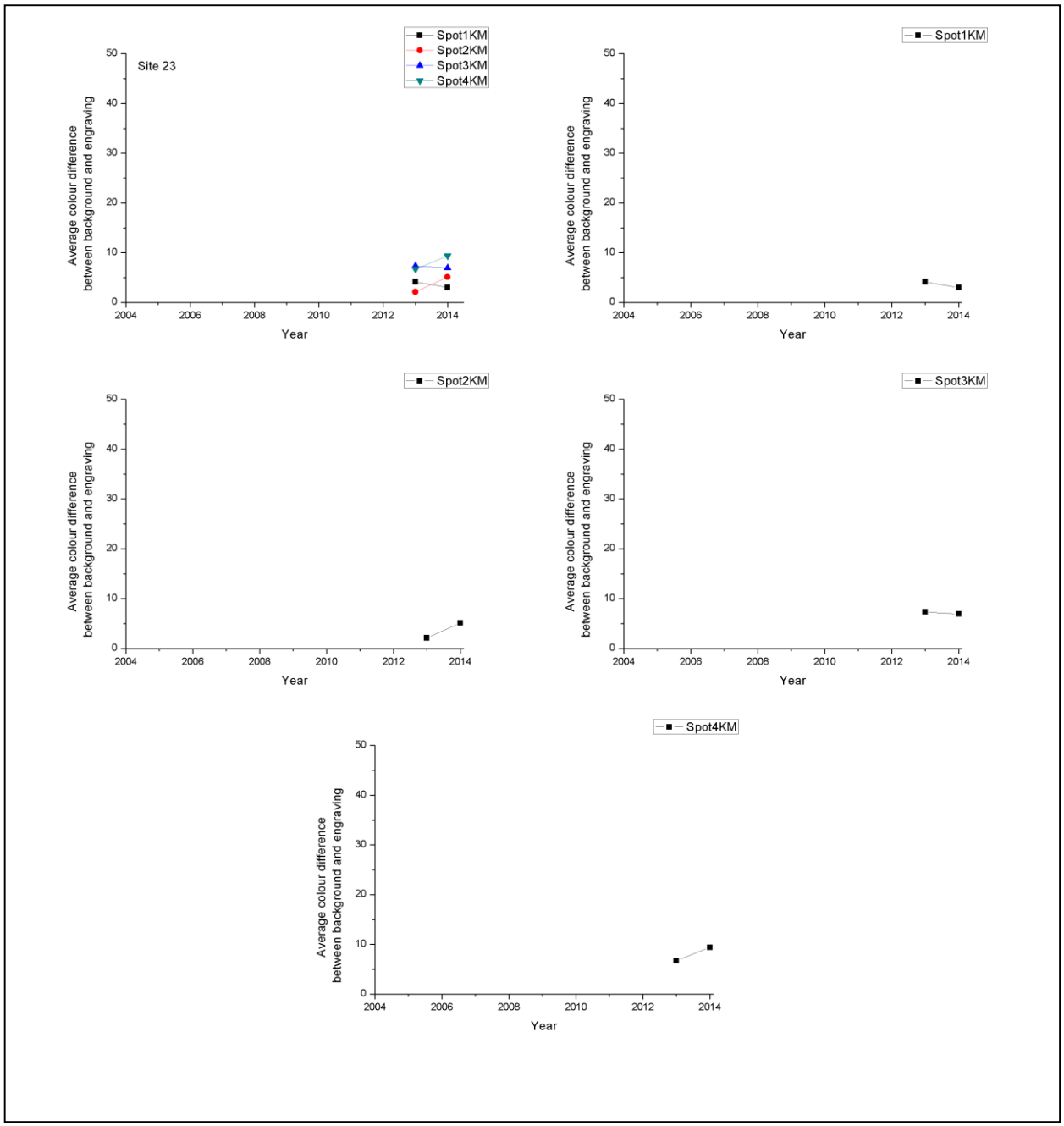


Figure 25: Colour differences between engraving and background for each spot examined at Site 23 – Yara East.

3.3.3 ANOVA ANALYSIS OF 2014 COLOUR MEASUREMENTS

In 2014, colour measurements were taken from the backgrounds and engravings on various spots of Aboriginal rock art at Northern and Southern sites on the Burrup peninsula. The data is in L*a*b* format. Northern and Southern sites are compared below for each of these variables separately. The Northern sites are found to be slightly lighter (in the engravings only, not in the backgrounds) and less red than the Southern sites. These differences are statistically significant.

L*

The variation in lightness across the sites is indicated in Figure 26. There is clear variation in lightness among the sites; site 6 in particular recorded no low lightness readings on background or engraving at any spots. The Northern sites 1 and 2 show a greater range of lightness but appear neither lighter nor darker on the whole than Southern sites.

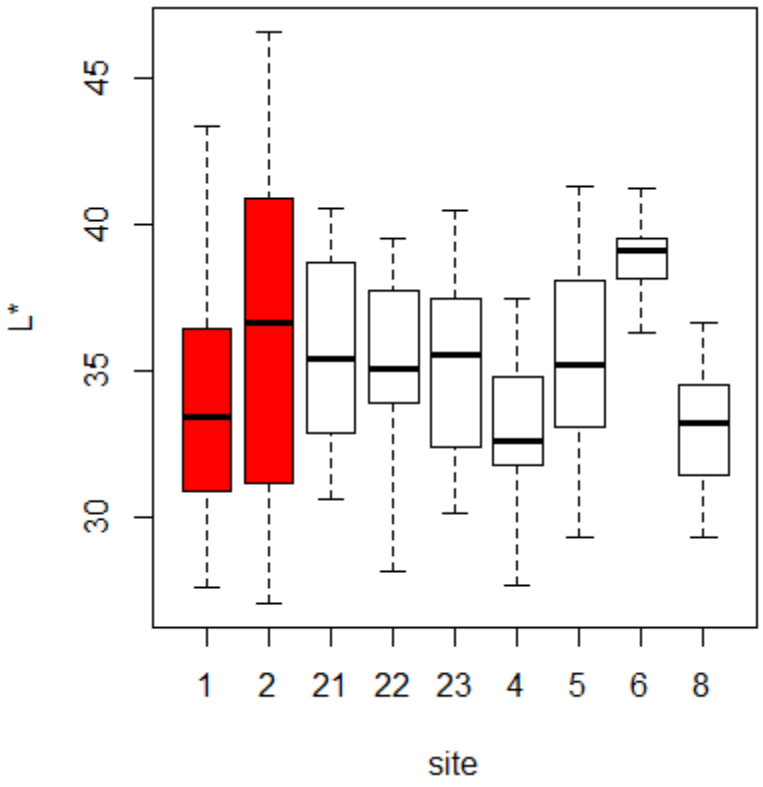


Figure 26. Boxplots of lightness L* at each site. Northern sites are coloured red in the plots.

The background is lighter than the engraving at only three of the 36 spots in the data. Figure 2 shows the contrast in lightness between background and engraving is greater at the Northern sites. (This means the engravings show up more clearly.) The background is slightly lighter on average at Southern sites, but the engraving is 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 0.005. (As shown inFigure 26 and Figure 27, the difference at Northern sites is primarily a greater contrast between background and engraving, not an overall increase or decrease in lightness at Northern sites.)

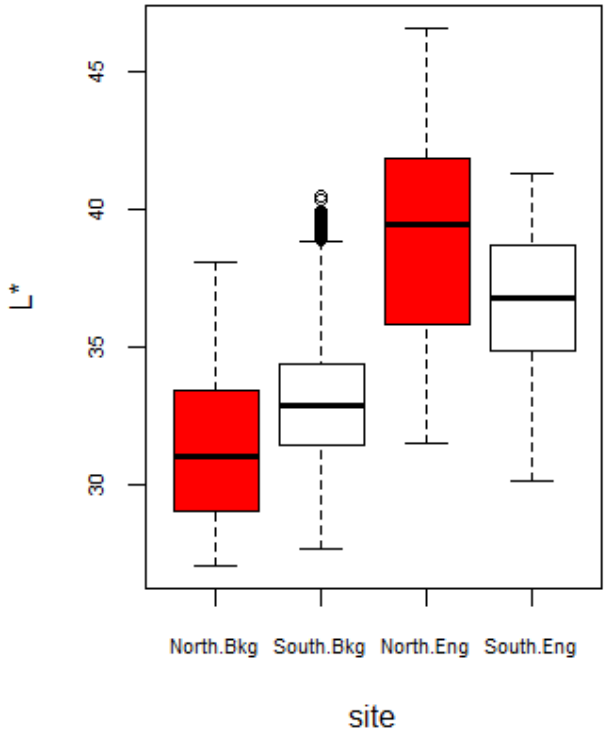


Figure 27. Boxplots showing how lightness varies between Northern and Southern sites on background and engraving. Northern sites are coloured red in the plots. Bkg stands for background; Eng for engraving.

a*

The green-red contrast across the sites is indicated in Figure 28. The sites are again clearly different from each other. Some Southern sites are noticeably more red than the Northern sites, but there is quite wide variation between the Southern sites.

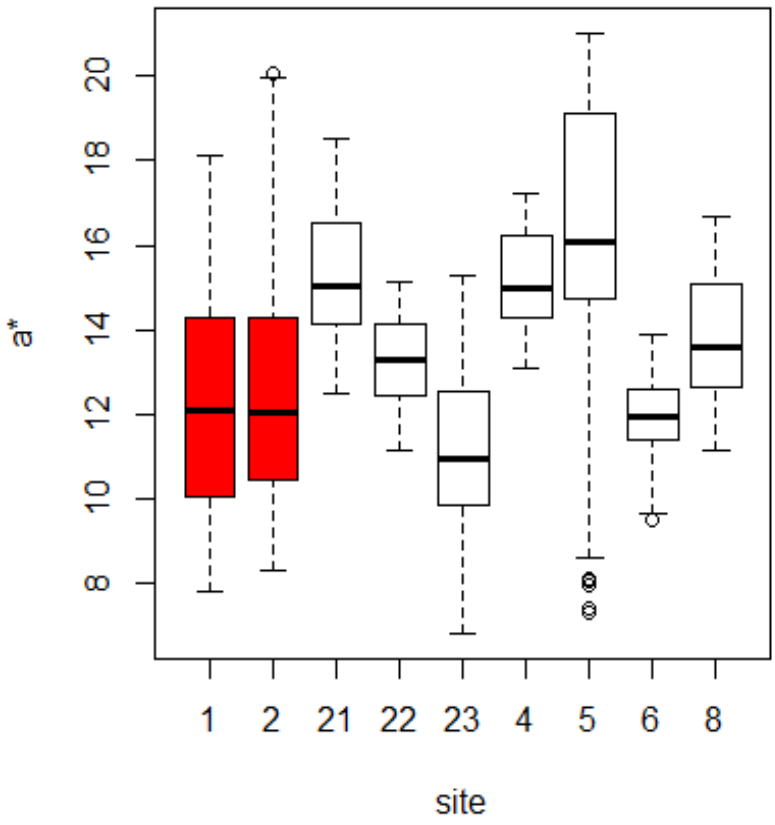


Figure 28. Boxplots of the green-red contrast a* at each site. Northern sites are coloured red in the plots (though their a* values indicate they are less red than some other sites).

At most Northern spots, the engraving is more red than the background; but at most Southern spots, the background is more red than the engraving. Figure 29 illustrates this effect in the averages of Northern and Southern sites (but the plots obscure it slightly by representing the most red backgrounds in the South and the least red backgrounds in the North as outliers).

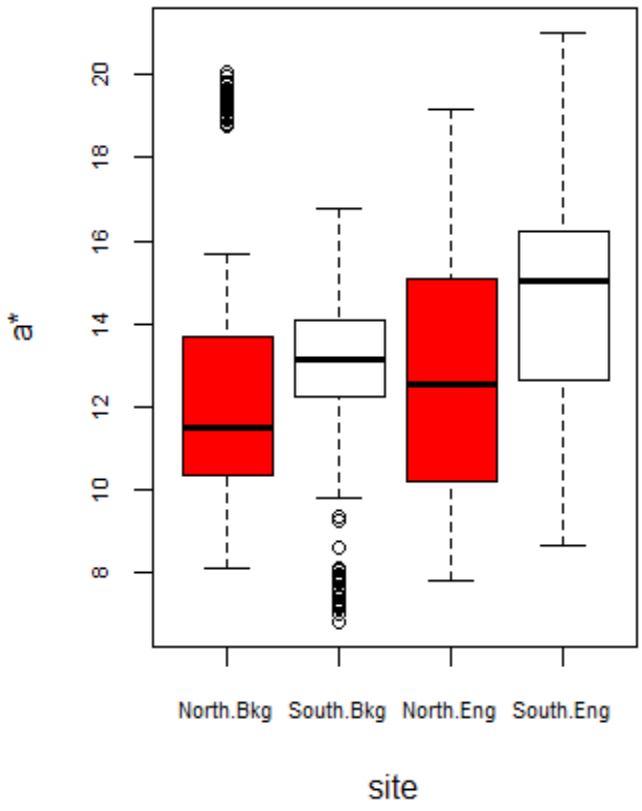


Figure 29. Boxplots showing how the green-red contrast varies between Northern and Southern sites on background and engraving. Northern sites are coloured red in the plots. Bkg stands for background; Eng for engraving.

The linear mixed effect model shows the North/South difference is significant for a*, with a p value of 0.002.

b*

The blue-yellow contrast across the sites is indicated in Figure 30. The sites are again clearly different from each other. Site 1 is slightly less yellow on average than the other sites, but Site 2 includes some of the most yellow observations.

At all Northern and almost all Southern spots, the engraving is more yellow than the background, as Figure 31 suggests. Figure 31 shows the blue-yellow contrast is very similar on the engravings in both the North and South of the peninsula, but Southern backgrounds tend to be slightly more yellow than those in the North.

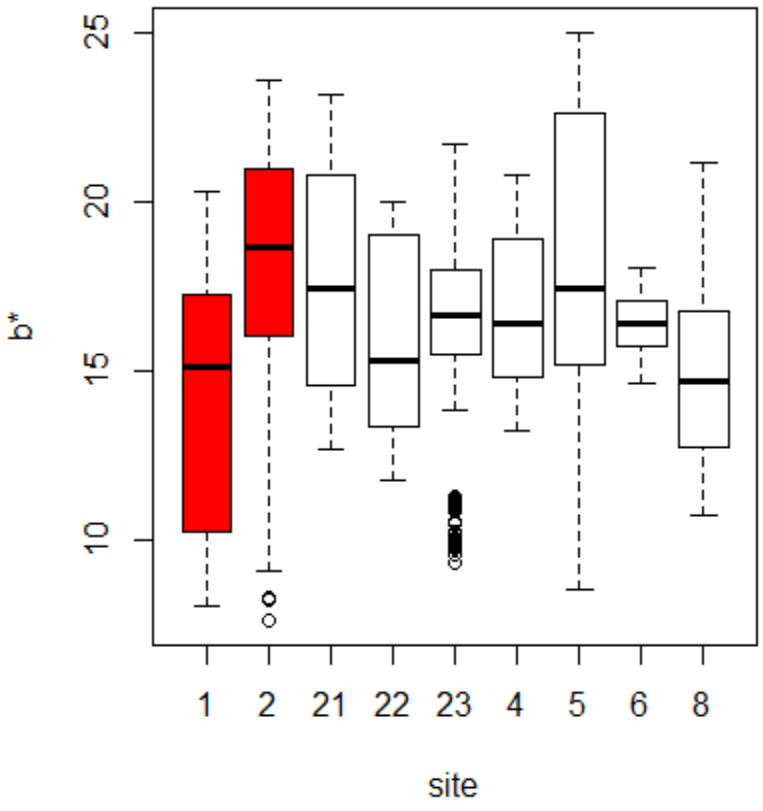


Figure 30. Boxplots of the blue-yellow contrast b* at each site. Northern sites are coloured red in the plots. Site 1 in particular is less yellow than the other sites.

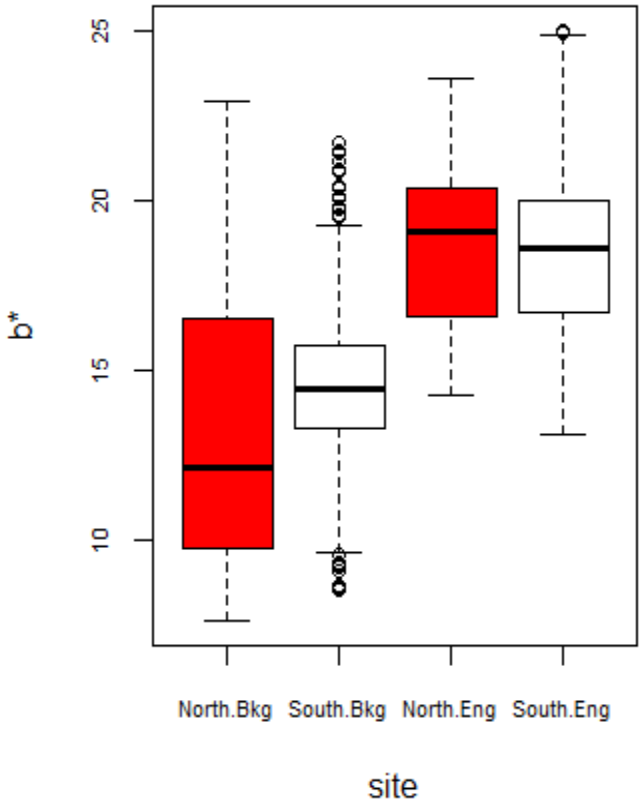


Figure 31. Boxplots showing how the blue-yellow contrast varies between Northern and Southern sites on background and engraving. Northern sites are coloured red in the plots. Bkg stands for background; Eng for engraving.

The linear mixed effect model shows the North/South difference is not significant for b*, with a p value of 0.185. This is unexpected; analysis of 2013 showed a significant difference between Northern and Southern sites not only in L* and a* but in b* also. The difference appears to be not that the contrast is in any less now than it was then, or any different in the three new sites added to the analysis, but that the measurements made in 2014 were more variable, and thus the difference which appeared significant last year (p value 0.03) is not so strongly evident in the data this year. (The observed differences between L* and a* in Northern and Southern sites are still observed to be statistically significant, in any case.)

4. Comparison between 2 spectrophotometers for colour measurement

The initial measurements (2004 to 2008) 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 19-21. (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 19 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 18: 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 32 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 32.) The residual standard error is 1.025 units.

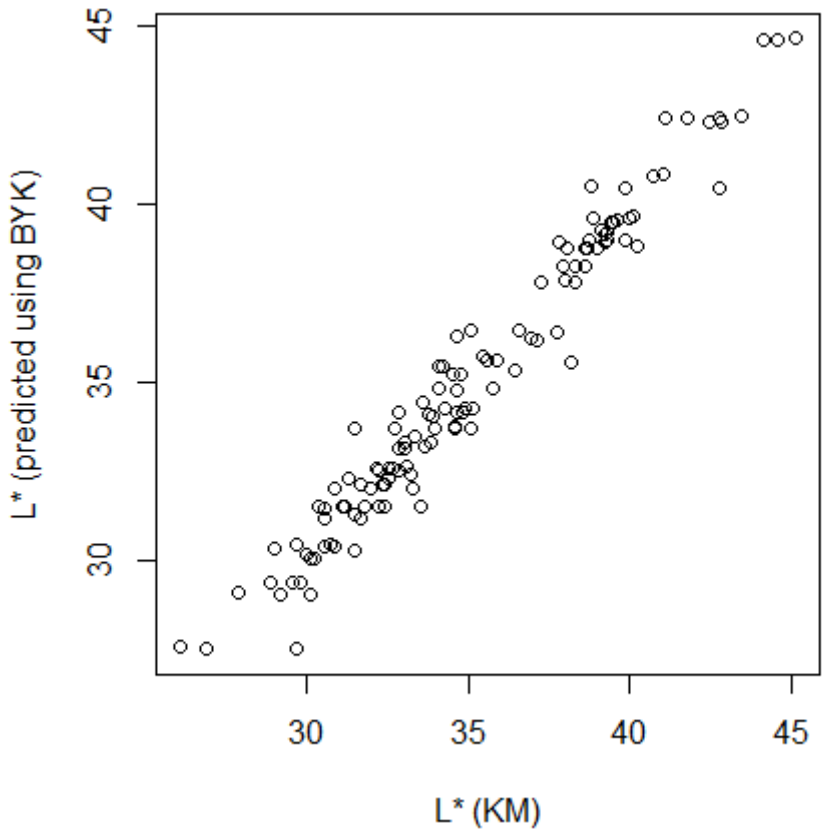


Figure 32: L* measurements on the KM machine and their predictions using BYK observations

Observations: a*

The a* observations are largely similar to those for L* measurements. Table 20 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 19 : 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 33 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.

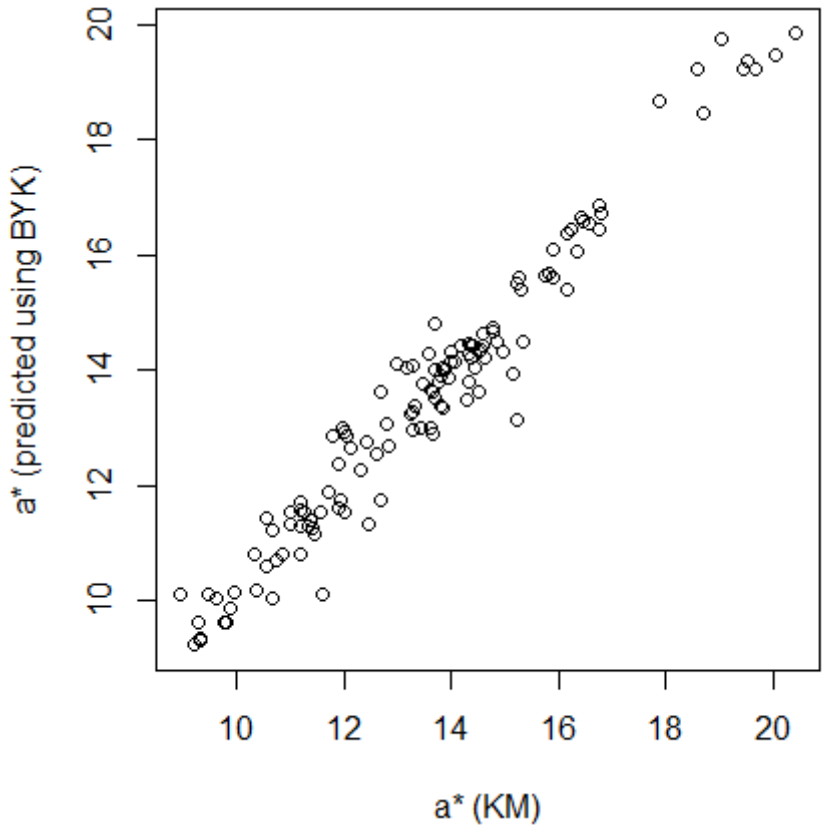


Figure 33: a* measurements on the KM machine and their predictions using BYK observations

Observations: b*

The results for b* are less clear-cut. Figure 34 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 20: 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 34 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.

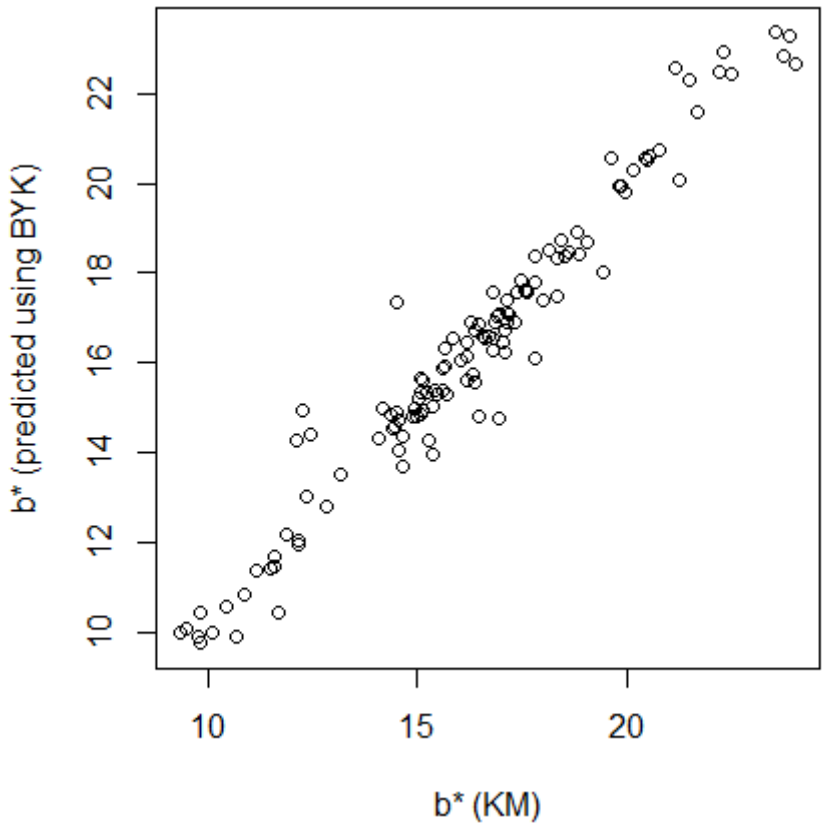


Figure 34: b* measurements on the KM machine and their predictions using BYK observations.

5. Conclusions

The measurements made in July 2014 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 2004–14 at either the control or test sites.

Three additional sites were added to the monitoring study as part of Yara Pilbara Nitrates Pty Ltd (YPNPL) Technical Ammonium Nitrate Production Facility Project, with these sites to be monitored for a further 3 years. The colour changes observed at these sites were comparable to other Southern sites, as well as the Northern 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 qualitative 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.

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.

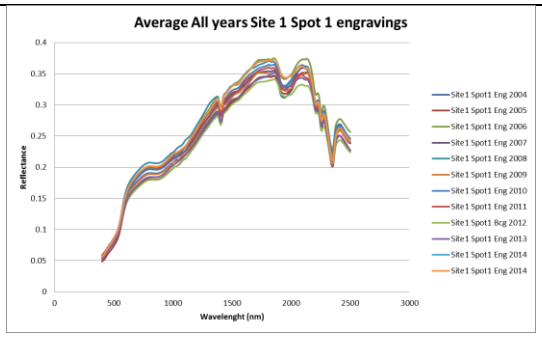
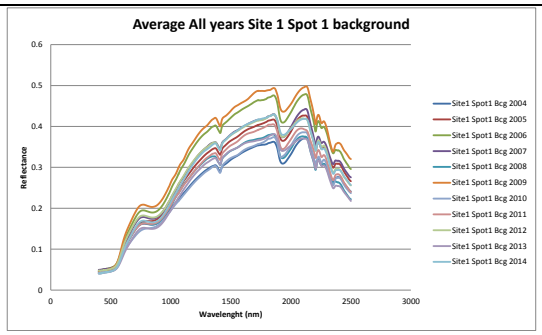
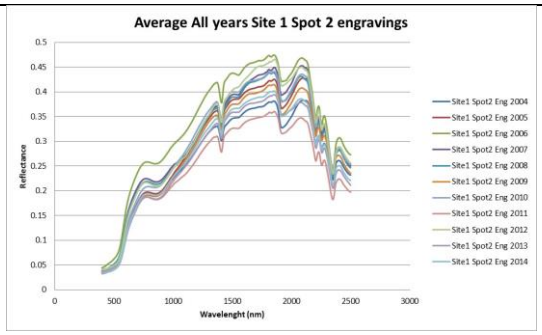
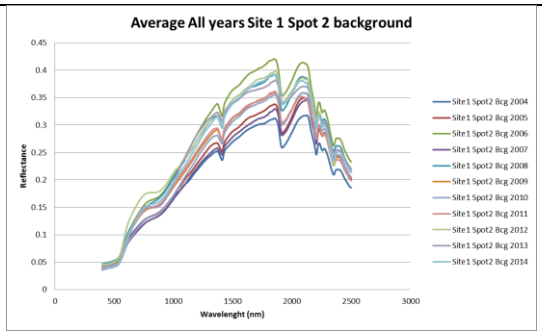
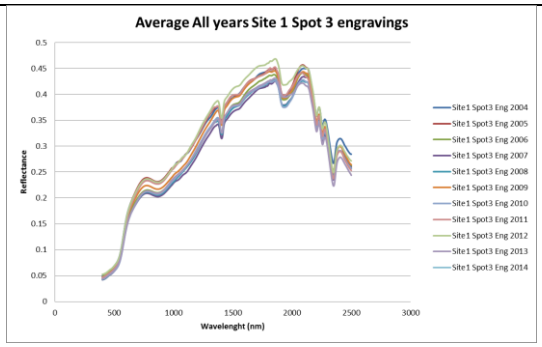
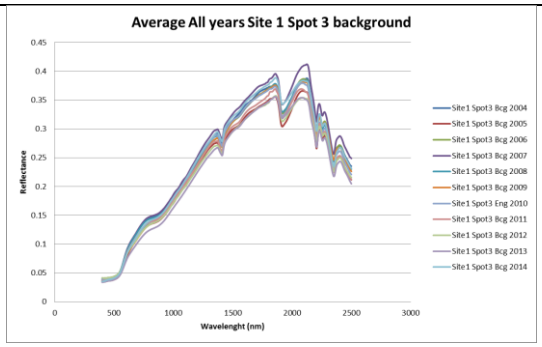
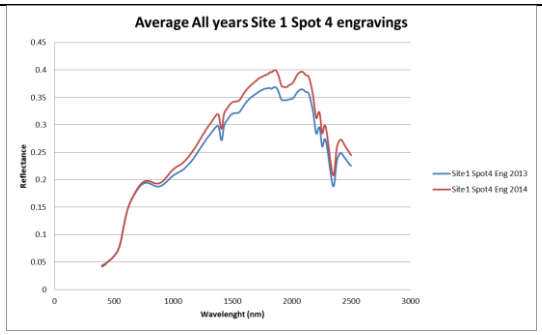
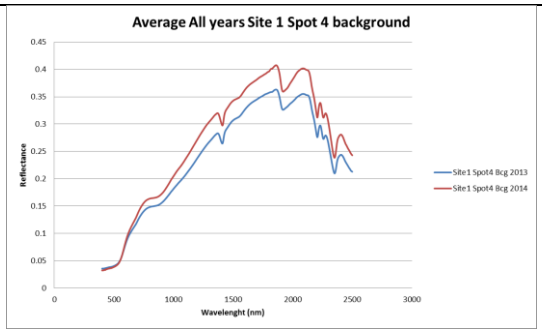
6.2 Spectral Results for 2004-2014

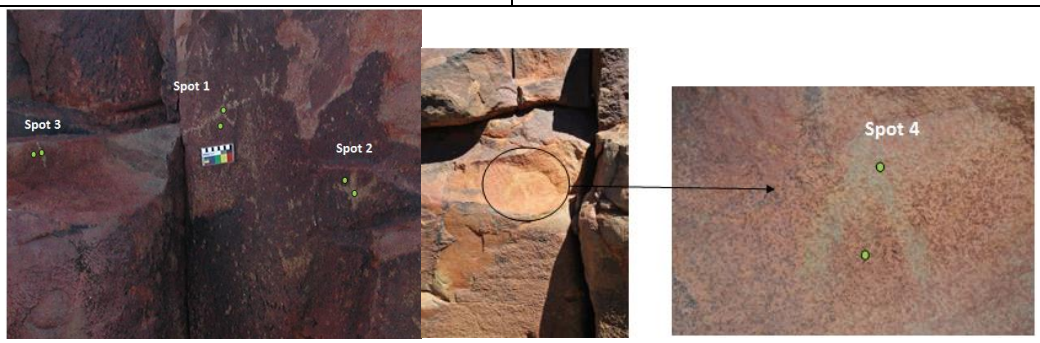
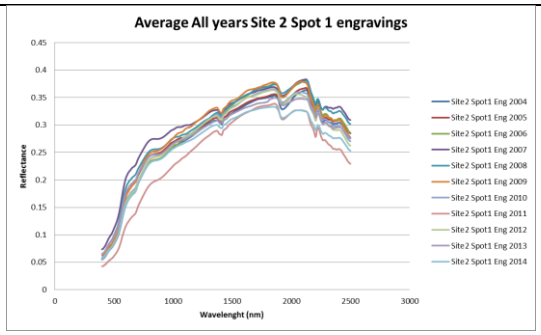
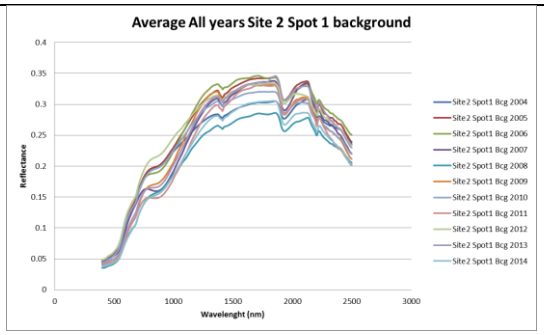
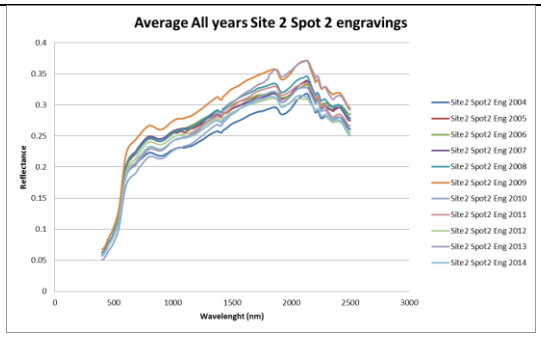
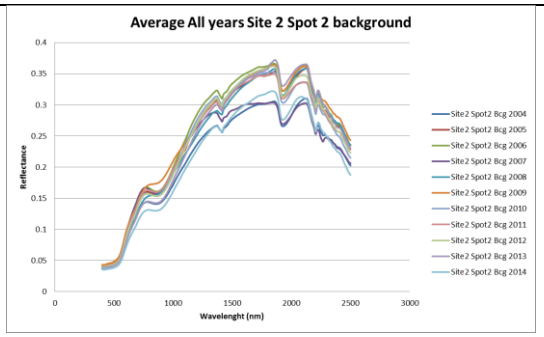
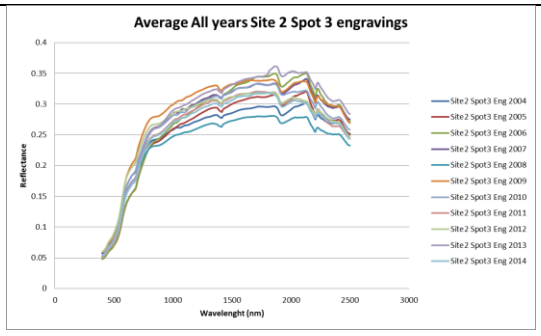
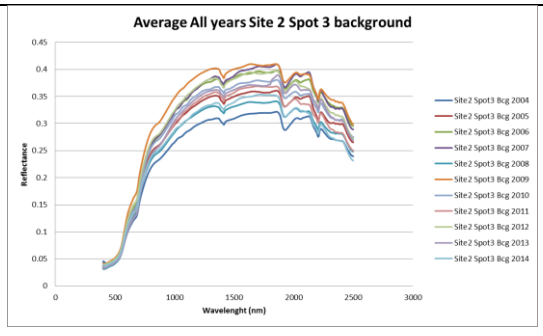
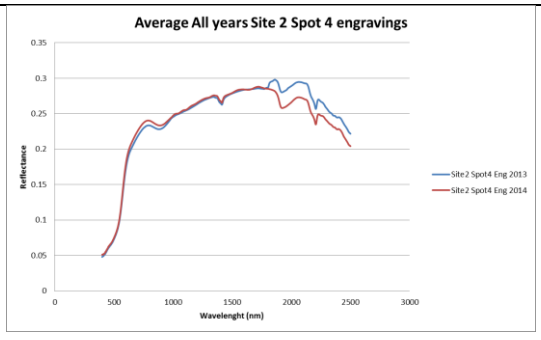
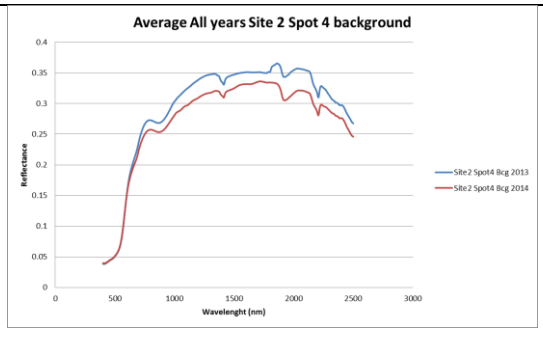
6.2.1 PICTURES AND SPECTRA

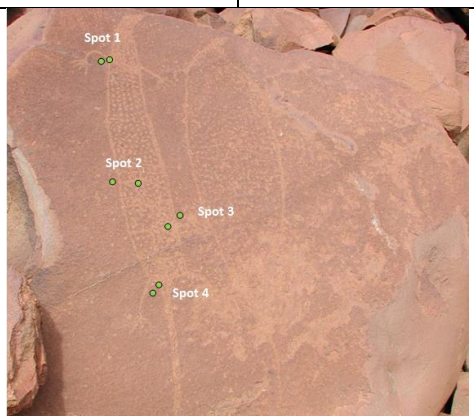
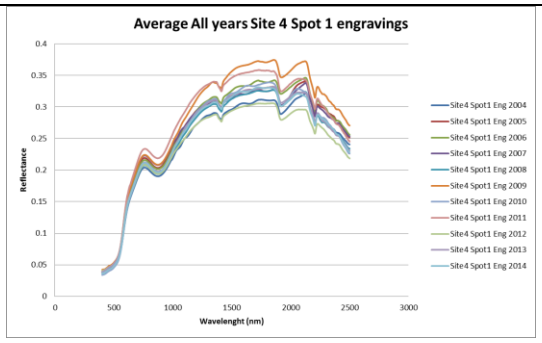
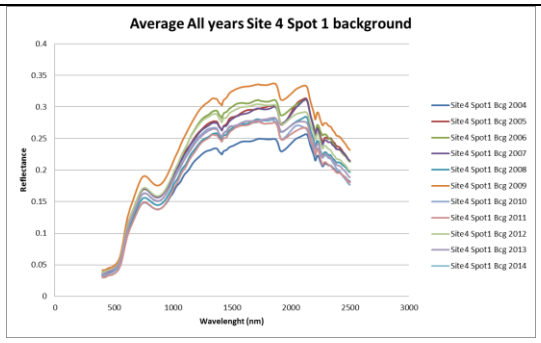
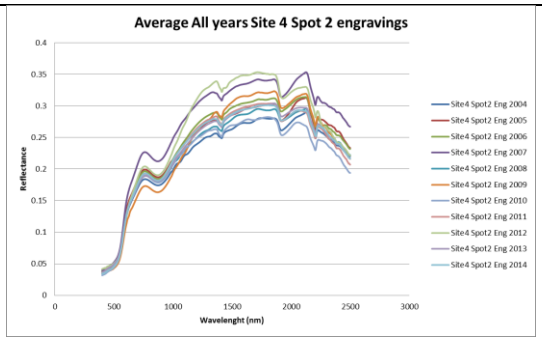
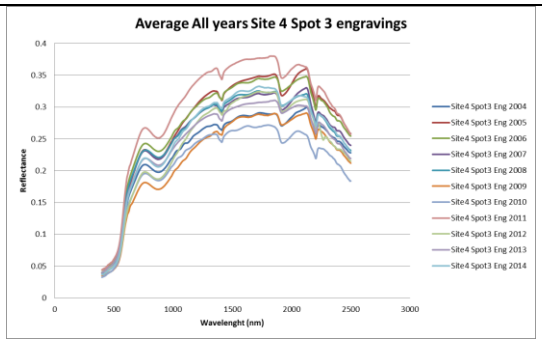
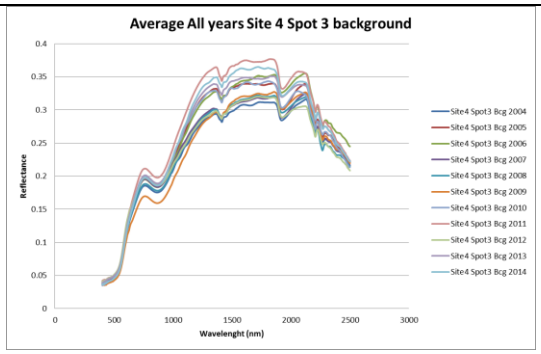
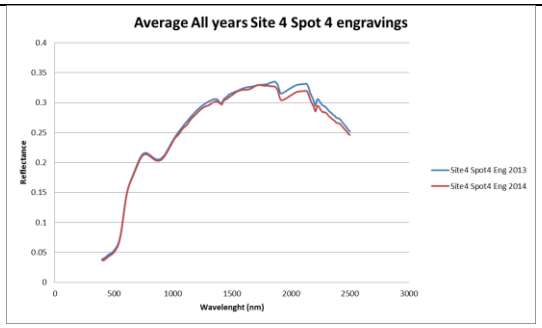
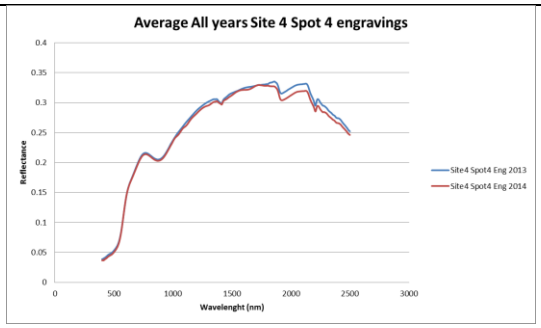
For each site, the description and interpretation include:

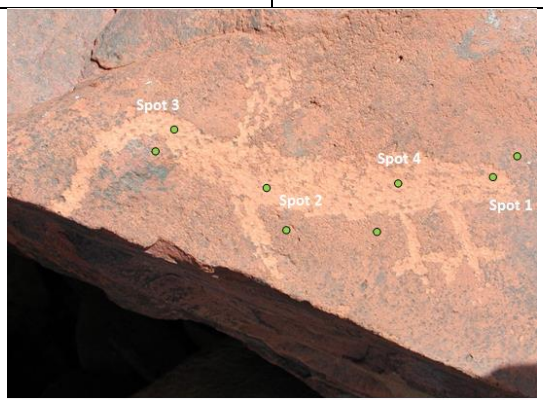
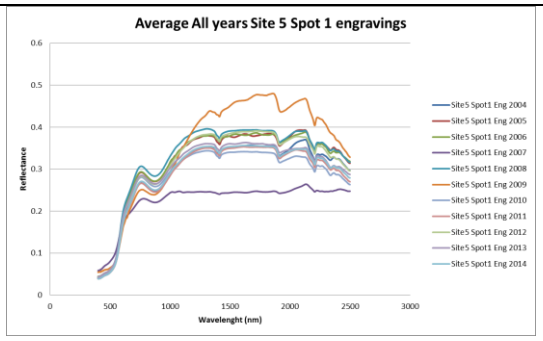
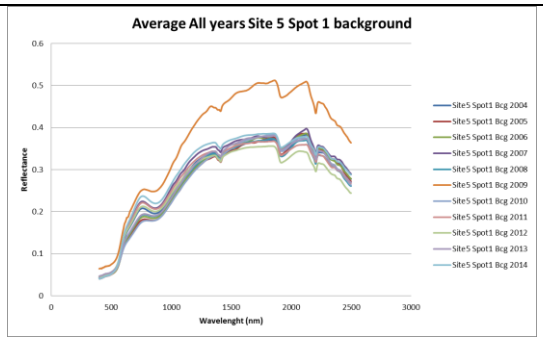
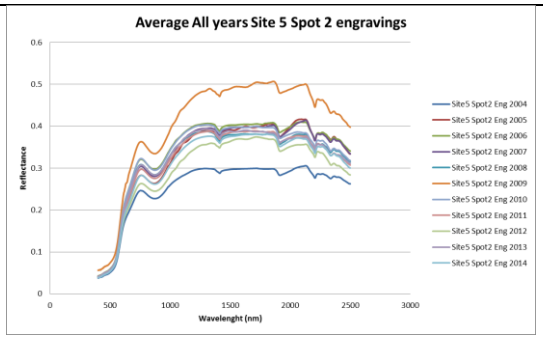
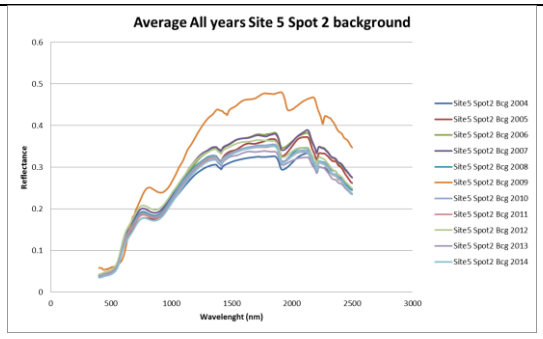
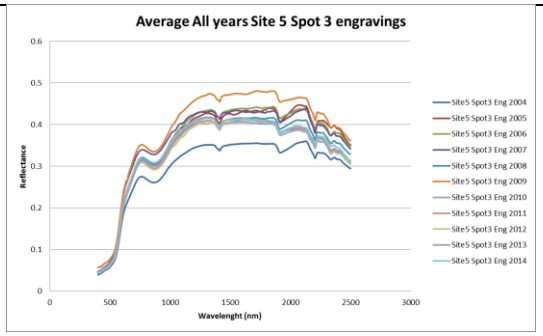
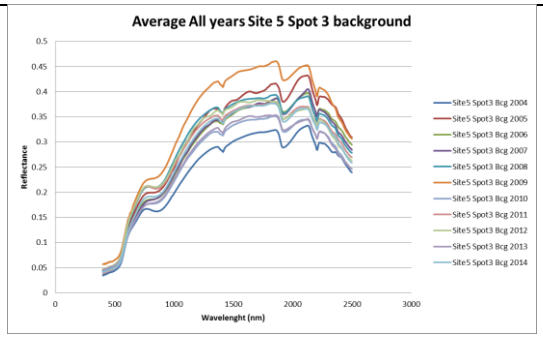
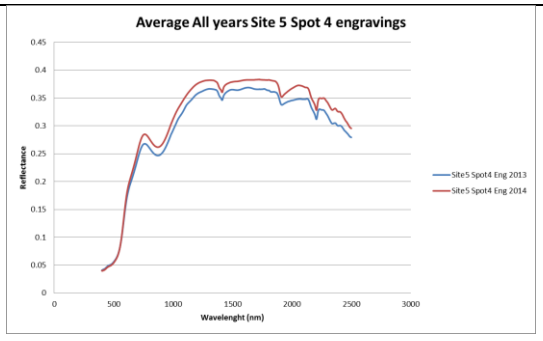
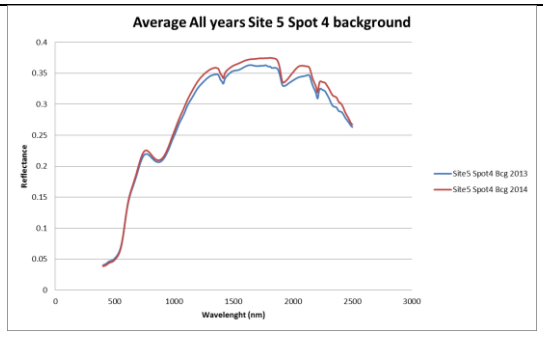
- A digital image of the engraving with the location of the measurements: spot 1, 2, and 3 and, from 2013 a new spot labelled 4 for both engraving and background. The new 4th engraving and background analysis spots have been added to the photographs.
- Comparison of the average spectra for the engravings and background for each of the three (or four) spots between 2004 and 2014.
- 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.

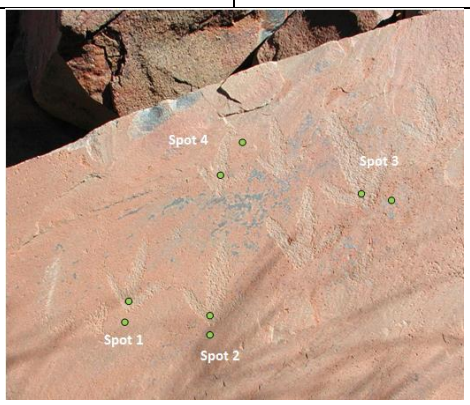
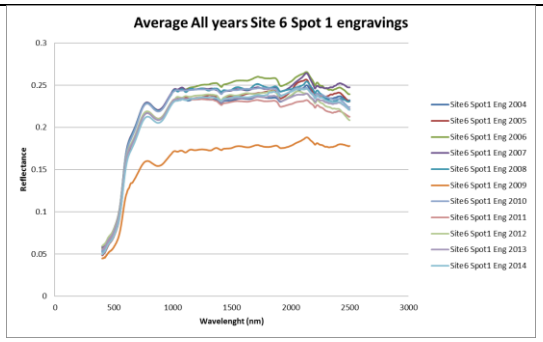
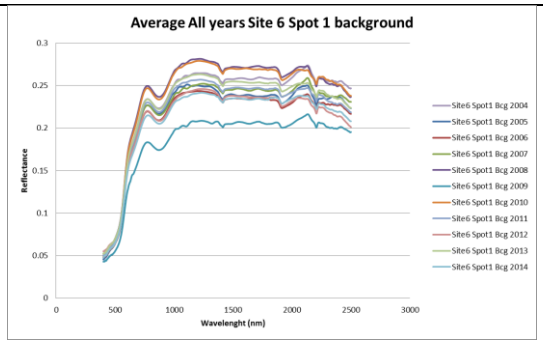
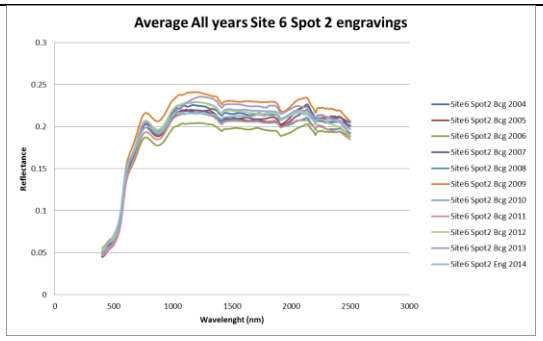
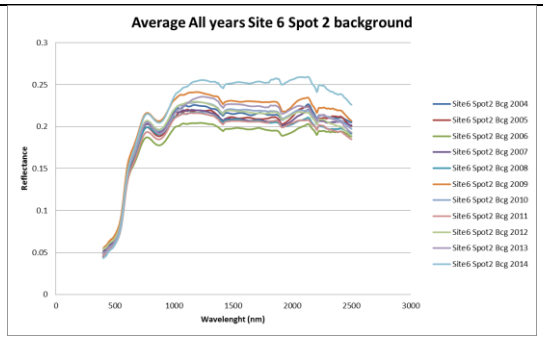
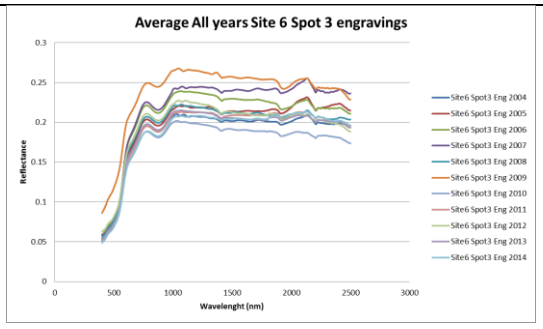
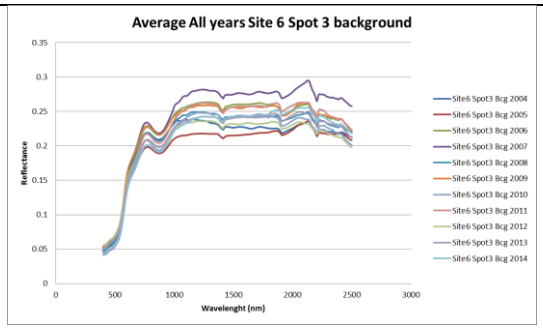
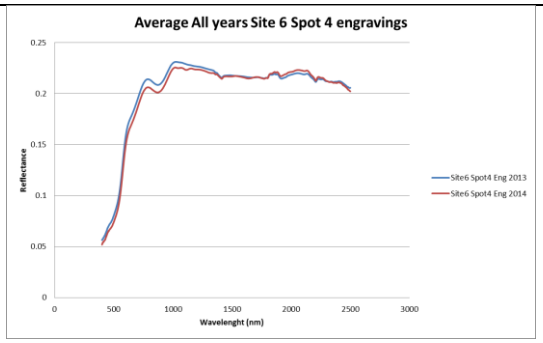
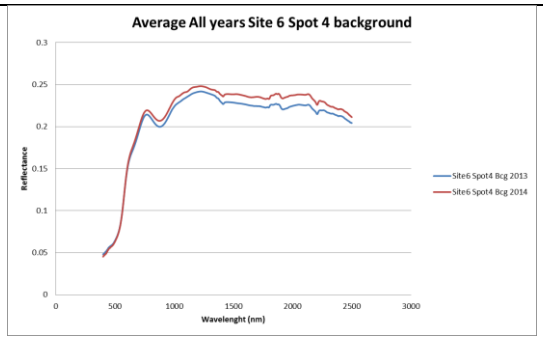
Figure 35: ASD FieldSpecPro and Konica Minolta CM-700dspectrophotometer operating on petroglyphs in the Burrup Peninsula (2013)

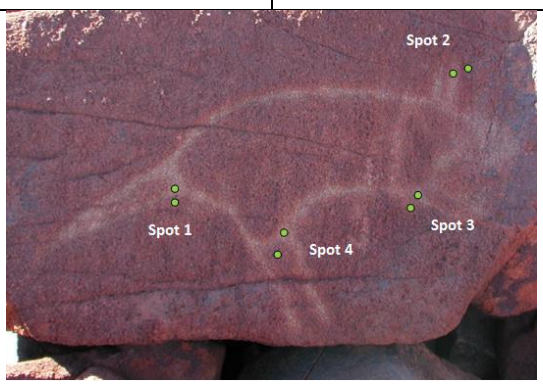
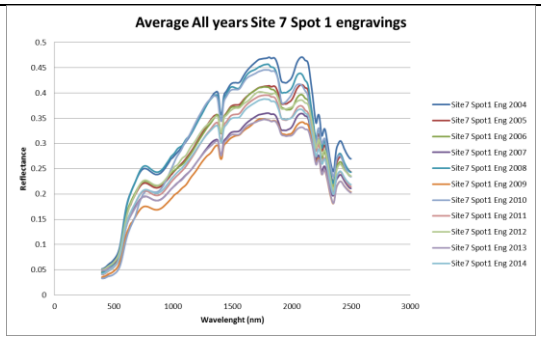
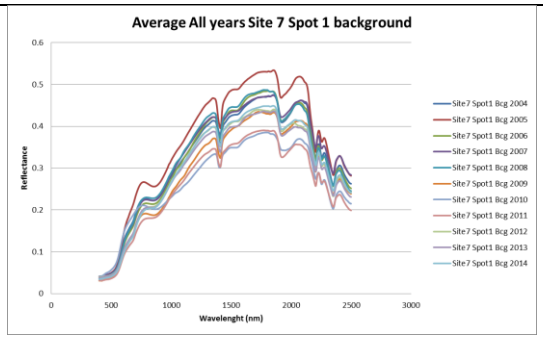
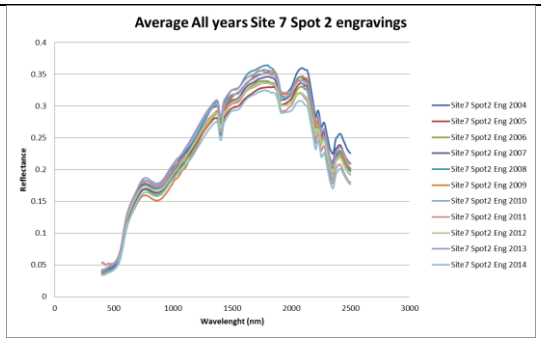
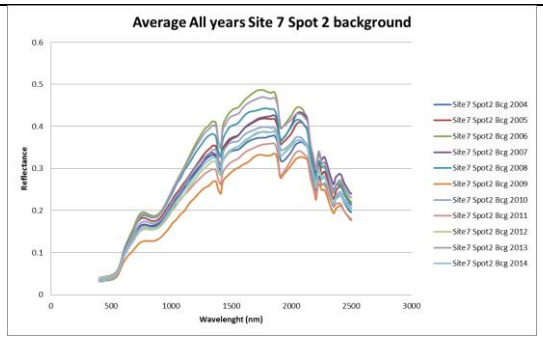
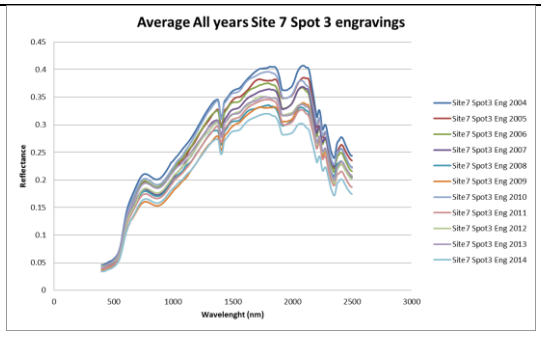
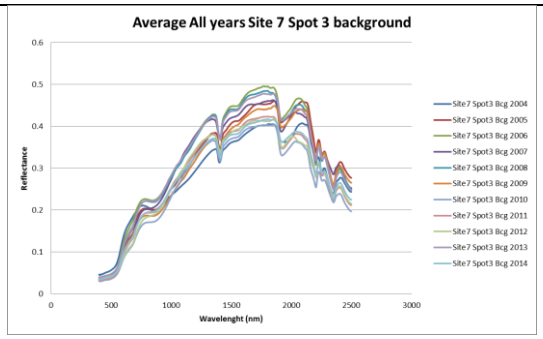
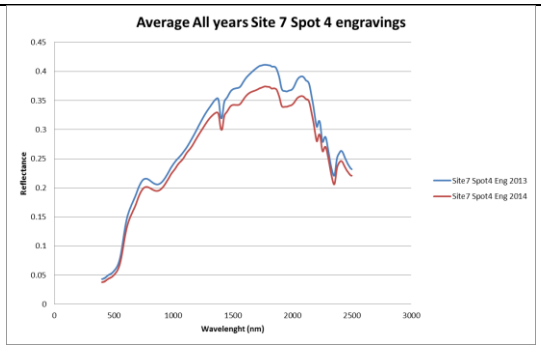
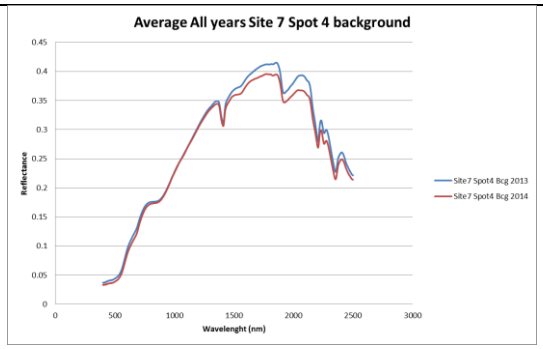
Location	Spectra Engraving	Spectra Background
Site 1		
Site 1 Spot 1		
Site 1 Spot 2		
Site 1 Spot 3		
Site 1 Spot 4		

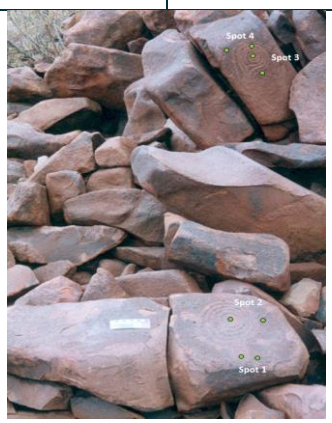
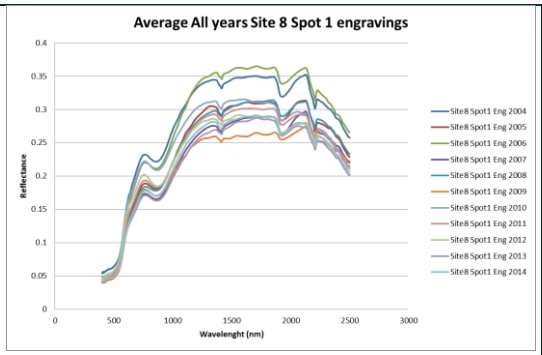
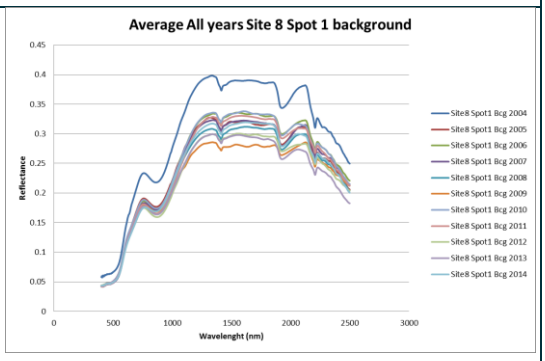
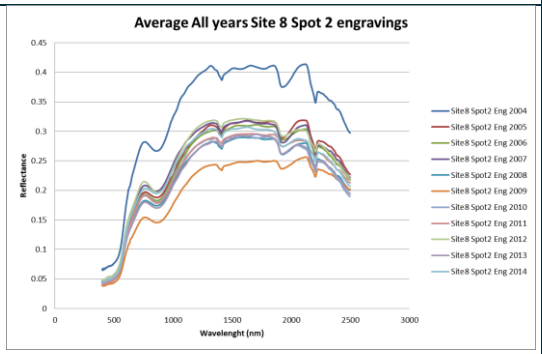
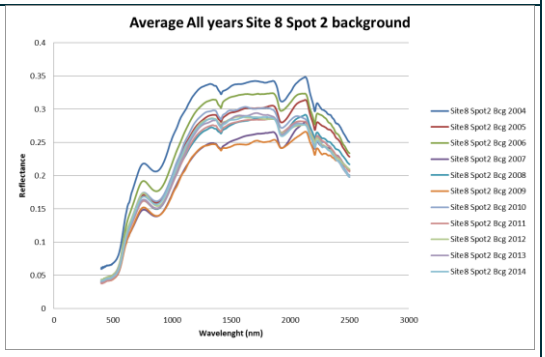
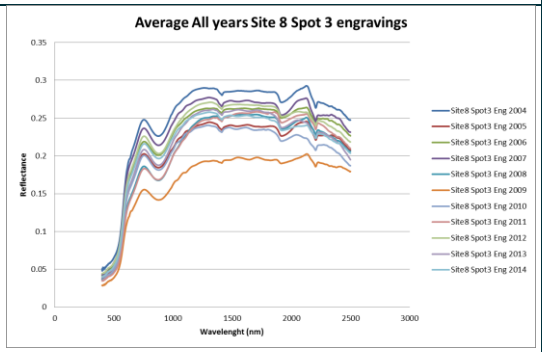
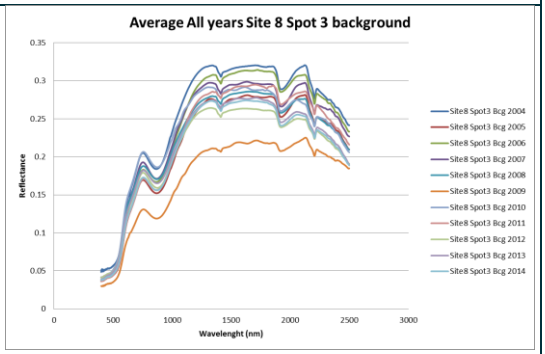
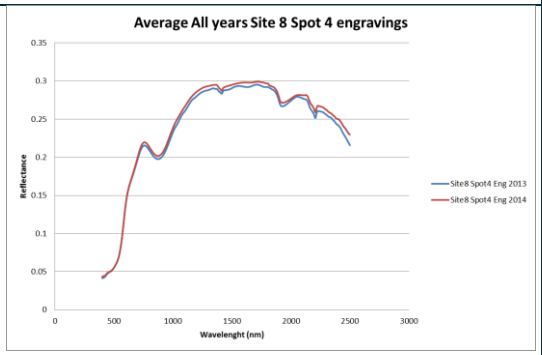
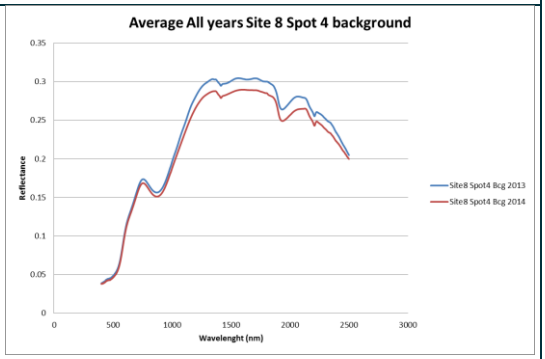
Location	Spectra Engraving	Spectra Background
Site 2		
Site 2 Spot 1		
Site 2 Spot 2		
Site 2 Spot 3		
Site 2 Spot 4		

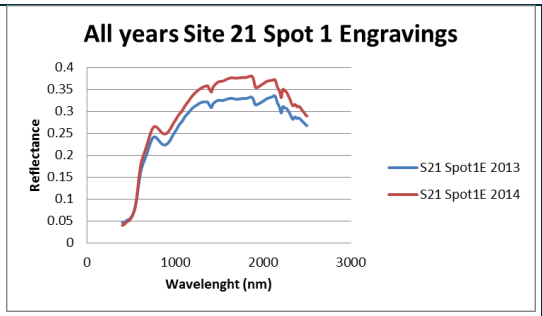
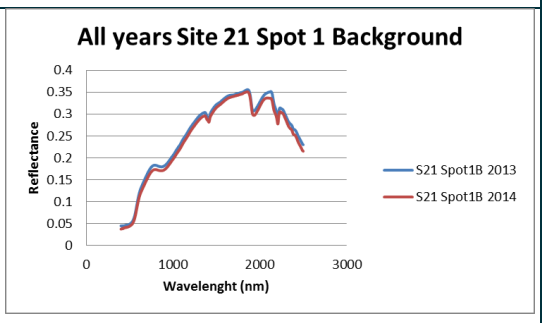
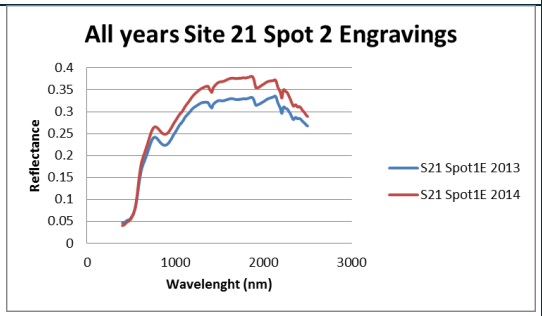
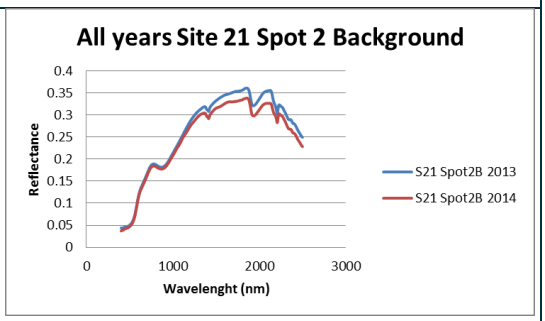
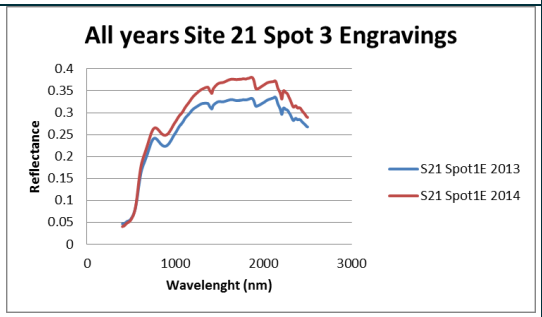
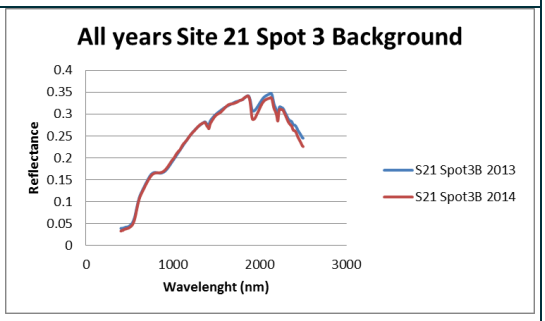
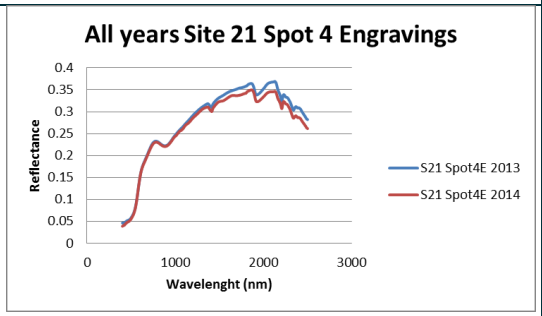
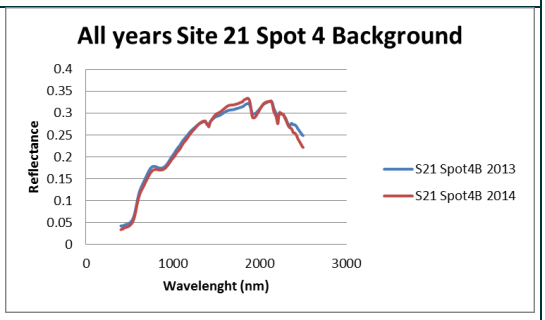
Location	Spectra Engraving	Spectra Background
Site 4		
Site 4 Spot 1		
Site 4 Spot 2		
Site 4 Spot 3		
Site 4 Spot 4		

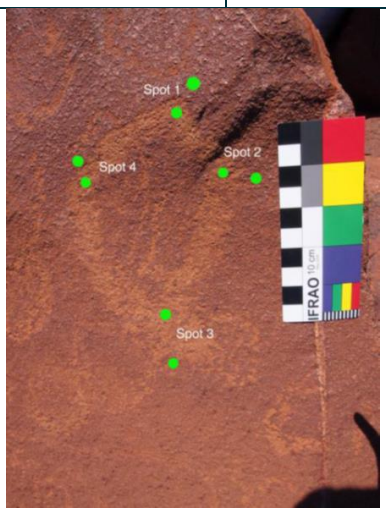
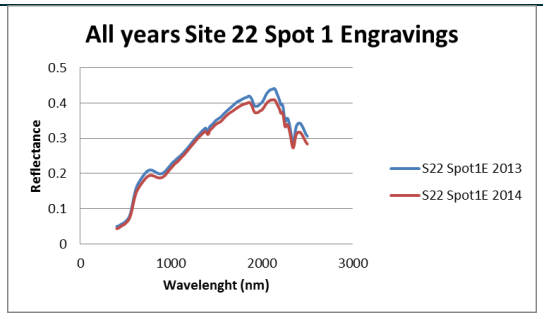
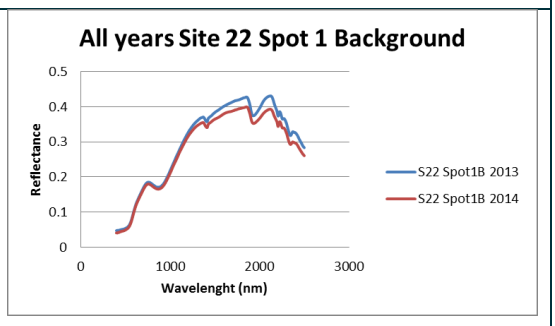
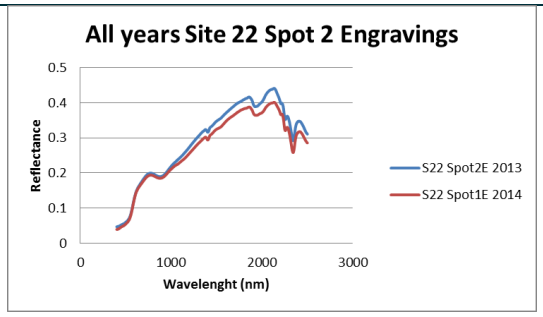
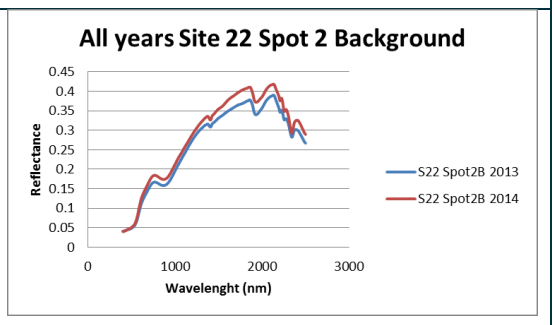
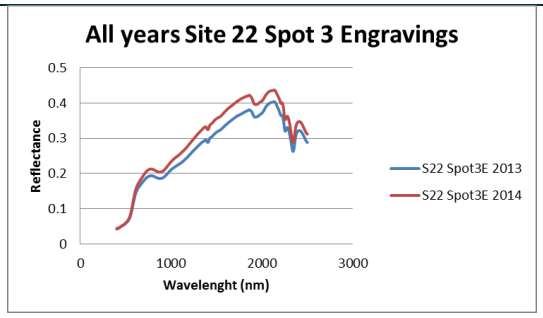
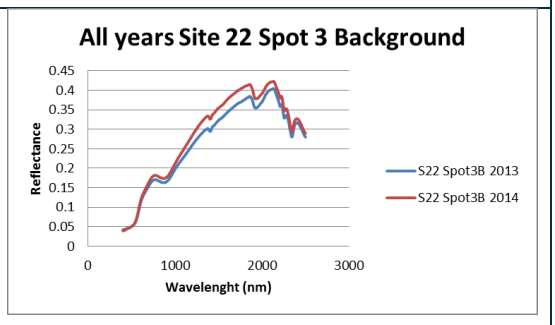
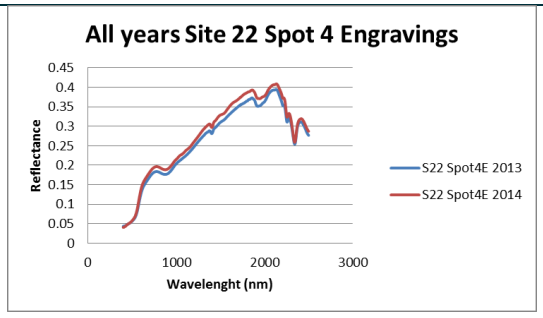
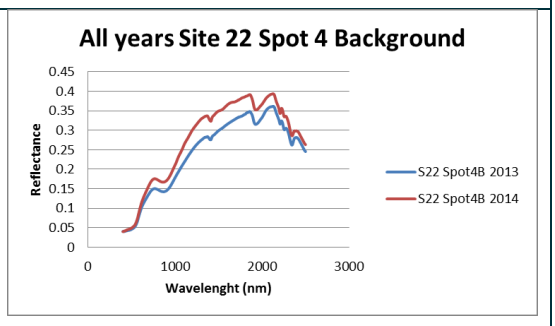
Location	Spectra Engraving	Spectra Background
		
Site 5 Spot 1		
Site 5 Spot 2		
Site 5 Spot 3		
Site 5 Spot 4		

Location	Spectra Engraving	Spectra Background
		
Site 6 Spot 1		
Site 6 Spot 2		
Site 6 Spot 3		
Site 6 Spot 4		

Location	Spectra Engraving	Spectra Background
		
Site 7 Spot 1		
Site 7 Spot 2		
Site 7 Spot 3		
Site7 Spot 4		

Location	Spectra Engraving	Spectra Background
Site 8		
Site 8 Spot 1		
Site 8 Spot 2		
Site 8 Spot 3		
Site 8 Spot 4		

Location	Spectra Engraving	Spectra Background
Site 21		
Site 21 Spot 1		
Site 21 Spot 2		
Site 21 Spot 3		
Site 21 Spot 4		

Location	Spectra Engraving	Spectra Background
Site 22		
Site 22 Spot 1		
Site 22 Spot 2		
Site 22 Spot 3		
Site 22 Spot 4		

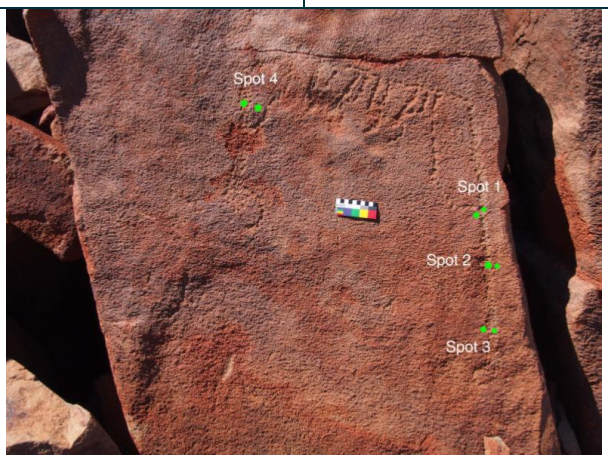
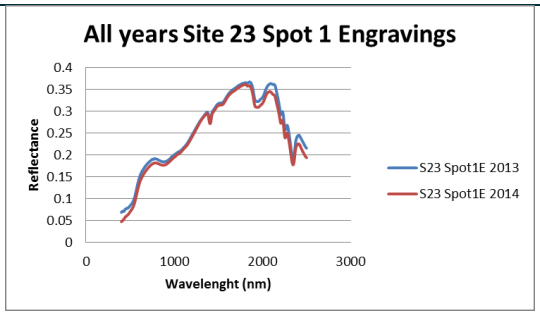
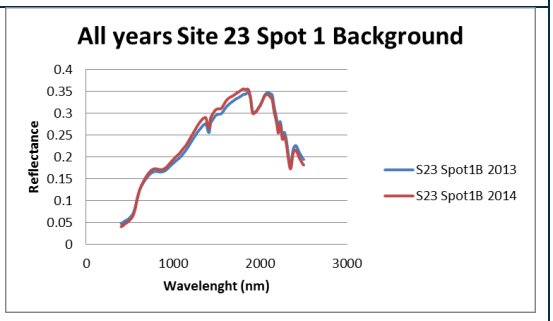
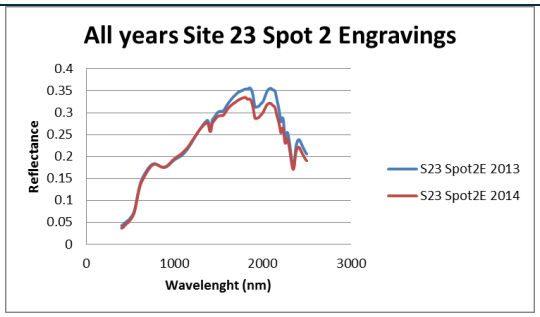
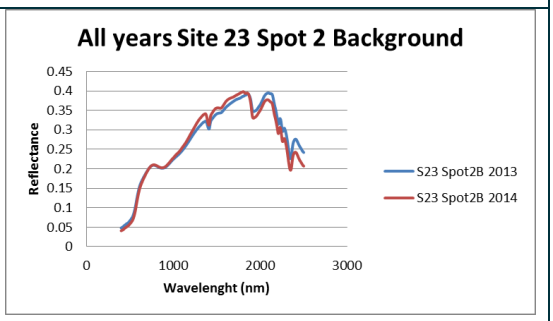
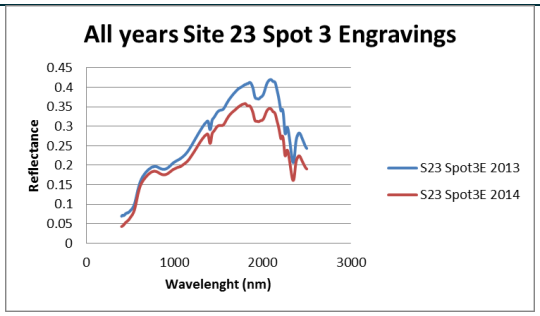
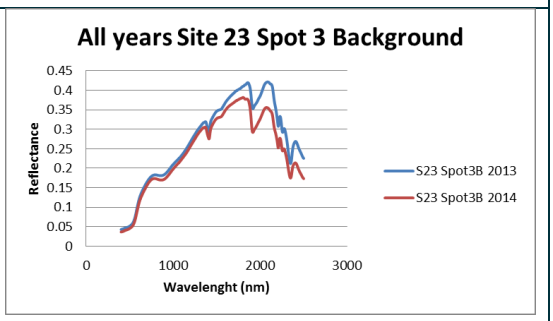
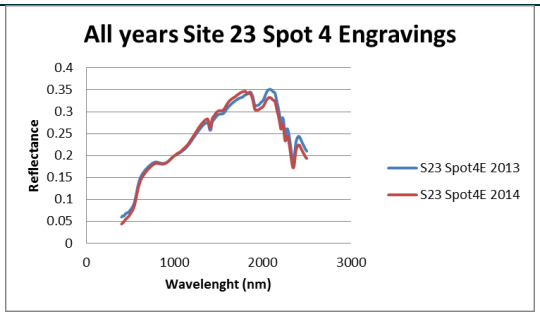
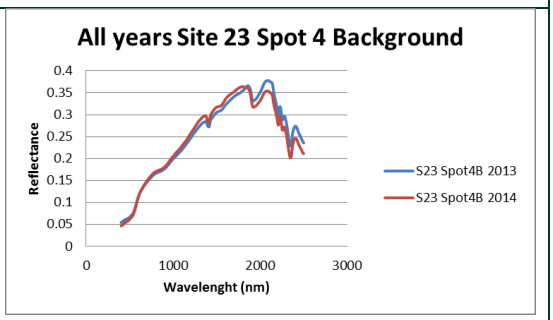
Location	Spectra Engraving	Spectra Background
Site 23		
Site 23 Spot 1		
Site 23 Spot 2		
Site 23 Spot 3		
Site 23 Spot 4		

Figure 36: 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 2014.

6.2.2 STATISTICAL ANALYSES FOR THE ASD SPECTRA

Reflectance 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 and then at ten sites in February and July 2014. 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.

Spectra were obtained from both the background and engraving at each of three spots on Aboriginal rock art at seven sites on the Burrup peninsula, in each of the years from 2004-2014. This document identifies numeric trends in the data; an important follow-up step is to interpret the spectra and their trends to obtain physically meaningful information.

Figure 37 shows the spectra for the background of the engraving at Spot 2 of Site 6 as an example of the data. The spectra appear very similar across the eleven years of observations. This is true of the data for background and engraving at all spots on all sites, though only one is shown.

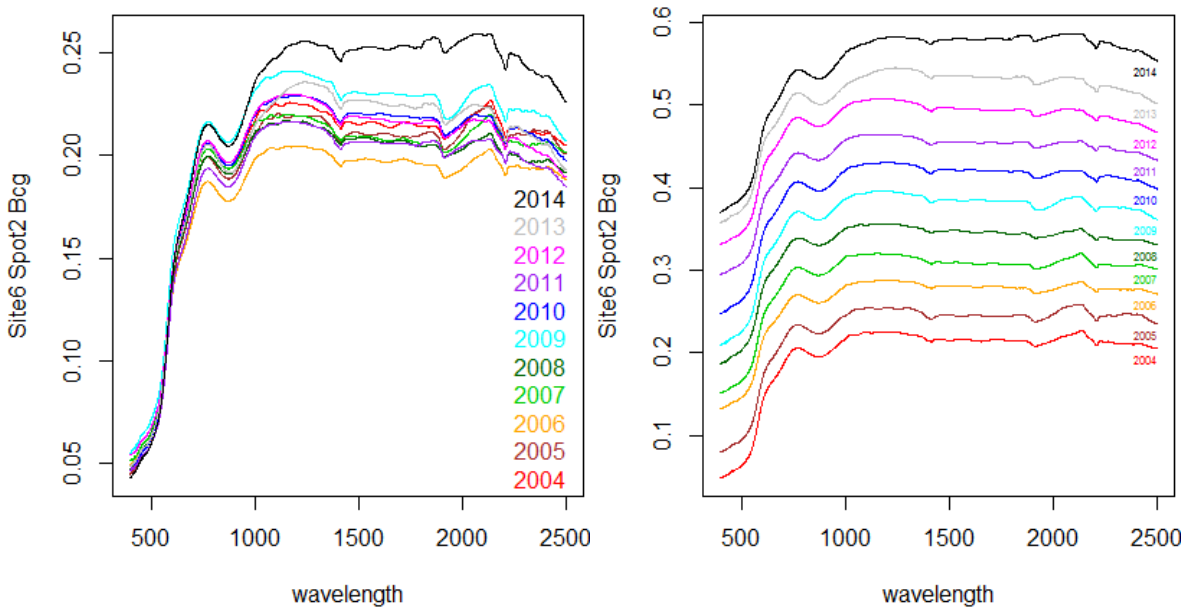


Figure 37. An example of the changes in spectra over time, plotted overlapping each other (left) and translated vertically to avoid overlap (right).

Are the slight changes in spectra due to random machine error, or a deterministic trend over time? One way to answer this is to plot the changes over time. This could be done for the values of the spectrum at particular wavelengths, or, via principal component analysis, for summary measures of the entire spectrum.

Figure 38 shows the reflectnce value of the spectrum in the trough at wavelength 873 and at the peak at wavelength 2129 from the data plotted in Figure 37. There appears to be an upward trend, though this is because the data have not been standardised; the intensity at 873 nm actually decreases if the spectra are standardised first. Figure 37 shows that the 2014 spectrum reaches higher intensities than the others, particularly at wavelengths above 1000 nm.

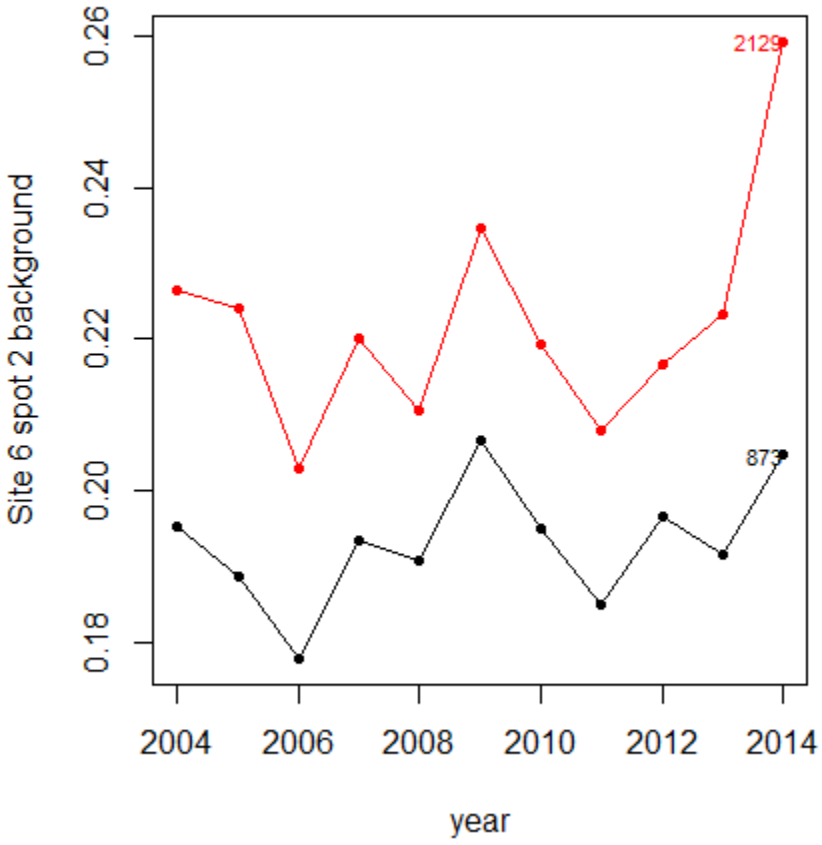


Figure 38. Values of the spectra at wavelengths 873 and 2129 (corresponding to one of the troughs and one of the peaks in Figure 37) for the background of the engraving at spot 2 of site 6.

The type of graph shown in Figure 38 focuses on only a few wavelengths. Principal component analysis summarises the change in the entire spectrum. The first principal component for background or engraving on each spot at each site is an 'average' of the spectra measured over 2004-2014. The second principal component highlights the direction of the most noticeable deviation from that average across the eleven years of data. Similar analysis could be performed on the third principal component but the analysis below focuses on just the first two principal components. (Most of the variation in the spectra is explained by these two components.) These are plotted for the example of the background of the engraving at spot 2 of site 6, in Figure 39.

(The first component is almost the same whether the 2014 data is included or not, but the second changes dramatically on the addition of 2014 data; as shown in Figure 37, the 2014 spectrum, while having similar shape to the others, is much higher at higher wavelengths.)

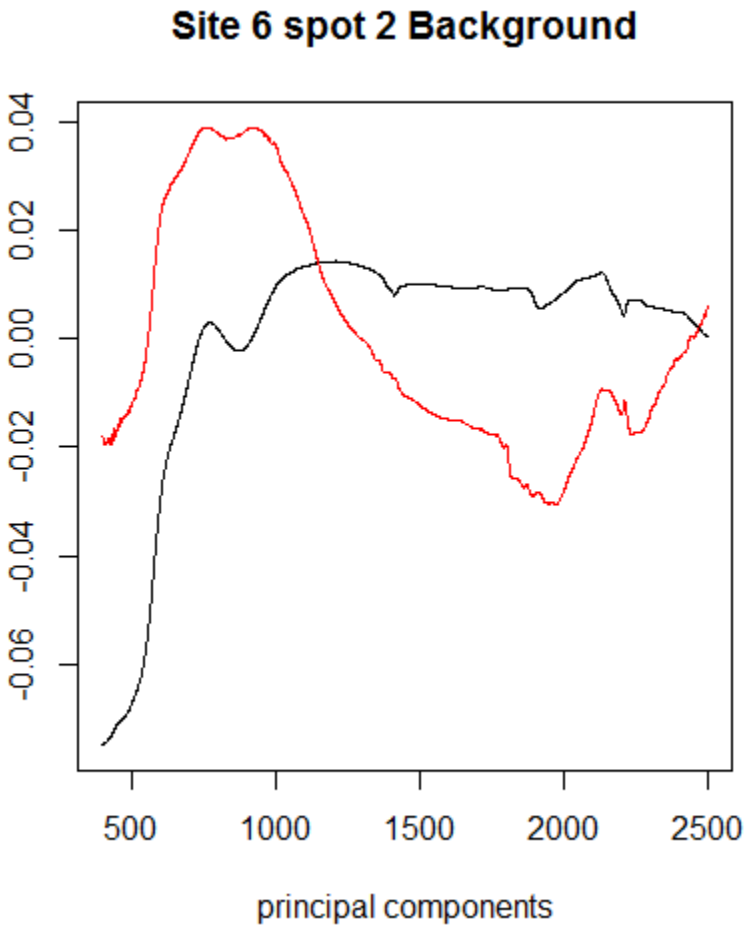


Figure 39. An example of the first two principal components, for the background of the engraving at spot 2 of site 6. Note that the vast majority of variation in the spectra – 99.7 % – is accounted for by the first principal component. The second principal component adjusts the first, for example accentuating the peak at wavelength 2129.

Note that the principal components are just directions in space, so multiplying them by -1 would make no difference to the analysis. The scale in Figure 39 is also immaterial.

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 into 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 decompositions of spectra at two different sites are plotted in Figure 40.

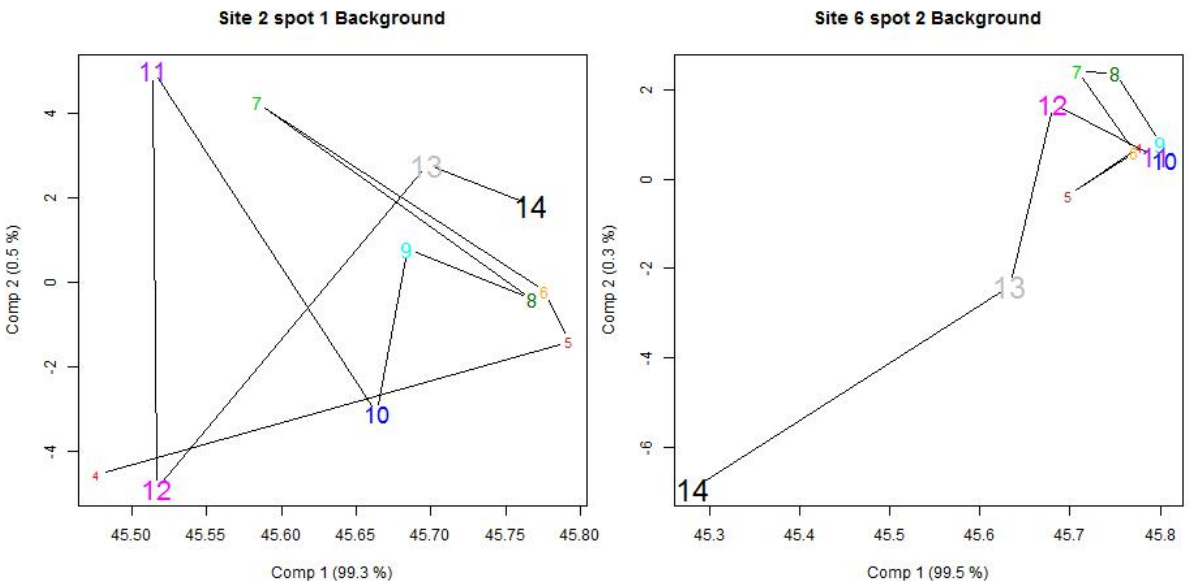


Figure 40. Score plot of the first two principal components of spectra recorded in the background of the engravings at spot 1 of site 2 (left) and spot 2 of site 6 (right). Data points are labelled 4-14, corresponding to the years 2004-2014 when data was recorded. (Labels for more recent data are displayed larger.)

Plots like those in Figure 40 were made for background and engraving at each spot at each site (excluding Spot 4, for which data are available only in 2013 and 2014, and Sites 21-23, for which data are available only in 2014; the graphs are meaningful only with at least three or four years' data). The 42 graphs thus produced are given in Appendix A . Horizontal axis labels on the graphs show that the first principal component in each case accounts for over 99 % of the overall variation – none of them deviate far from the average for that spot and site. This is perhaps the overriding observation from the analysis of how the spectra change over time.

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 the left plot in Figure 40; the scores on each principal component oscillate randomly, producing a trendless 'squiggle' indicating only random variations to and fro over the years. (Several of them are markedly different from the corresponding graphs produced before 2014 data became available; this reinforces that any apparent trends on most of the graphs are merely random variation.)

The right plot in Figure 40, however, does show a systematic trend, at least over the last three years, towards the bottom left corner. The principal components for this data were plotted in Figure 39; the trend thus indicates, among other things, that the peak at wavelength 2129 is less emphasised in more recent data. (This can also be seen in the plots in Figure 37. That the 2014 spectrum is different from the others is also apparent in both Figure 37 and Figure 40.)

As noted above, the scale in Figure 40 is immaterial; thus it makes no difference whether the trends on the plots are up or down. Whether the trends are statistically significant can be tested by regression analysis. Those in which trends in the scores on either the first or second principal component appear greater than expected by chance (significant at a 5 % level for the individual spectra) are listed below.

- Site 1 spot 3 background
- Site 2 spot 3 background
- Site 4 spot 1 engraving and background
- Site 4 spot 2 engraving and background
- Site 5 spot 2 background
- Site 5 spot 3 engraving and background
- Site 6 spot 2 background
- Site 6 spot 3 background
- Site 7 spot 2 engraving
- Site 7 spot 3 engraving and background

This list is similar to that given before the 2014 data became available, but contains some differences. This suggests that some of the apparent trends were merely random fluctuation. As noted previously, about four false positives might be expected with the number of tests being performed, and it turns out that there are four 'significant' results in each list not present in the other, which tends to indicate that these are merely products of random variation.

Even those that still appear significant after the 2014 data is added are not very strongly significant; applying a Bonferroni correction, a test of whether any of the trends is truly significant gives a p value of 0.12. Previously there had been a strong trend in the spectra of the background at Site 6 Spot 2, but, while the 2014 spectrum for these data is noticeably different from the others, it modifies the trend rather than reinforcing it – again suggesting that the result could be no more than random fluctuation.

Before the 2014 data was obtained, the analysis showed a change in engraving whenever a change in background was observed, suggesting that engravings were more vulnerable to change than backgrounds. The new data do not support this conclusion, however; several of the observed trends in the list above are for background only.

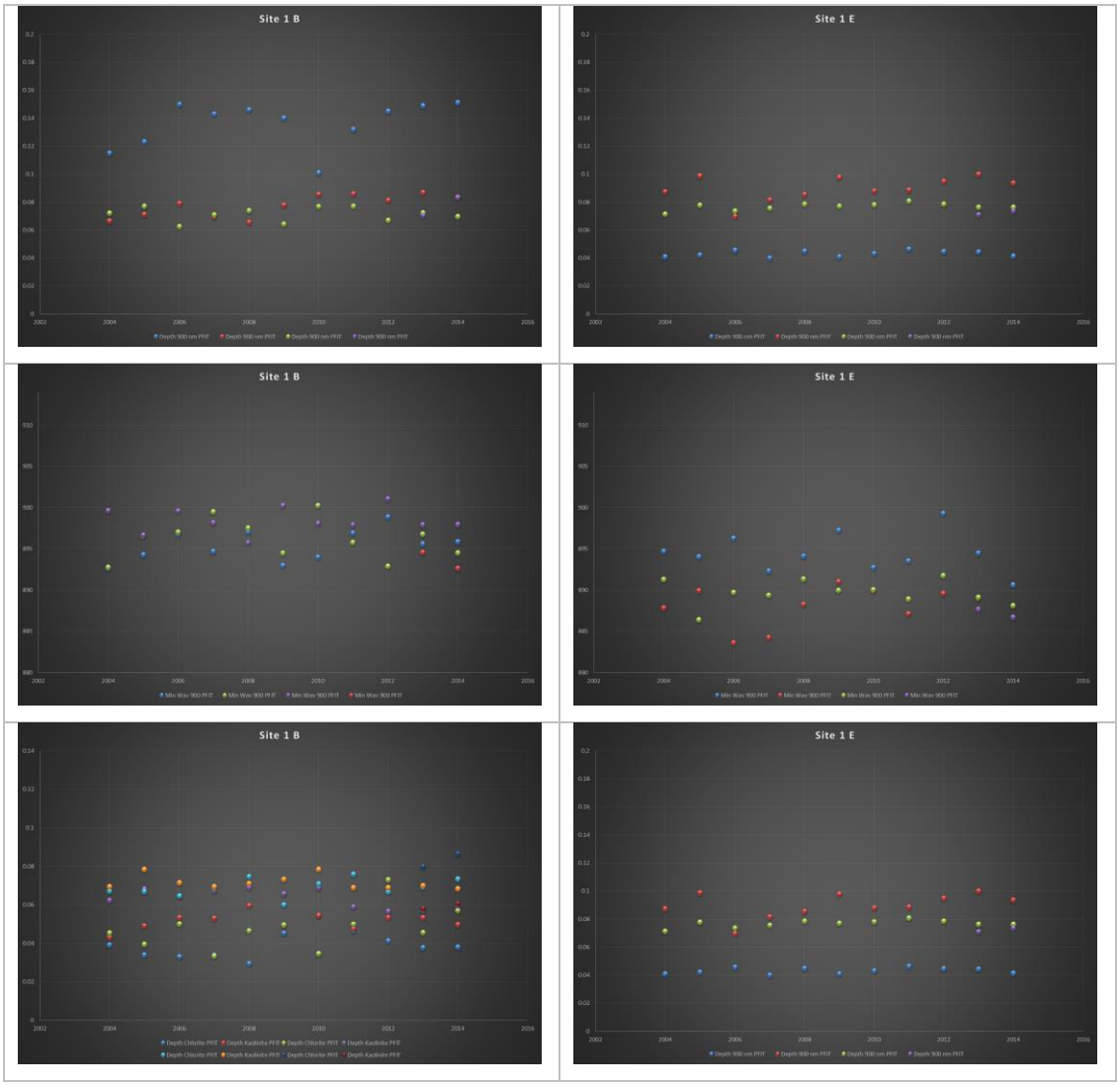
Changes were also detected previously only at southern sites, which are closer to the port, town and industrial sites, but at neither of the northern control sites. However, this is again contradicted by the 2014 data.

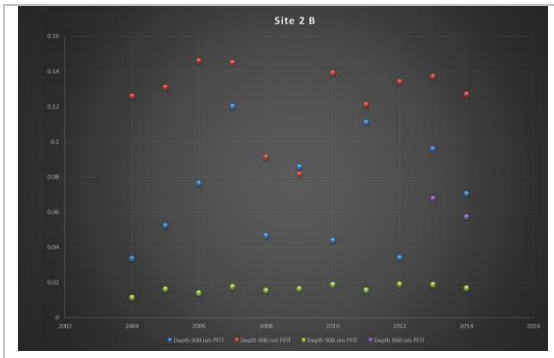
The comment from the previous analysis remains pertinent, in any case: the physical meaning (see next paragraph Spectral Parameters) of any changes in spectra should be established before concluding that real changes in the rocks are occurring. Even a statistically significant trend (and the recent data casts doubt on whether any of the trends are in fact strong enough to be considered statistically significant) 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.

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 at 2250 nm after local Hull removal - Depth Chlorite (residual mineral from the fresh rocks)
3. The depth of the kaolinite at 2206 nm after local Hull removal (Depth Kaolinite) and, when present, gibbsite (Depth Gibbsite) absorptions (secondary minerals resulting from the weathering of the primary minerals)

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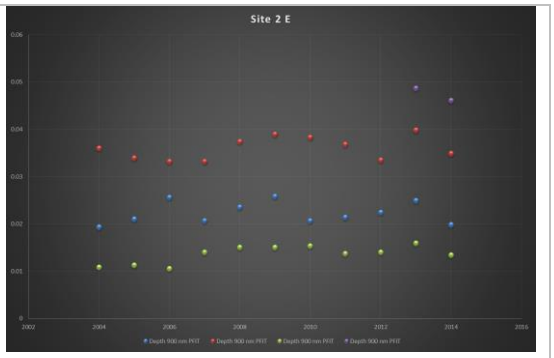
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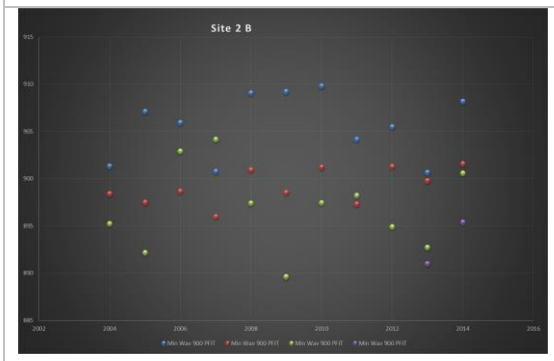
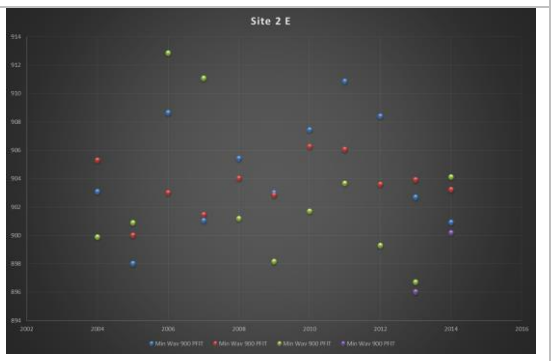

Site 2 B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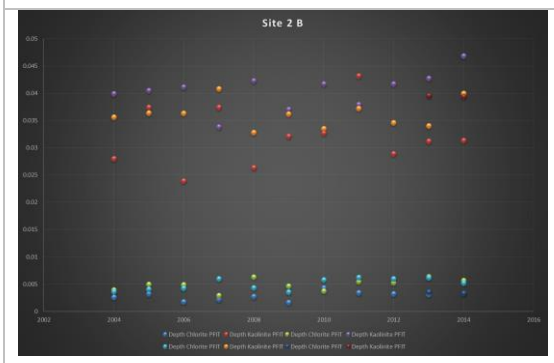
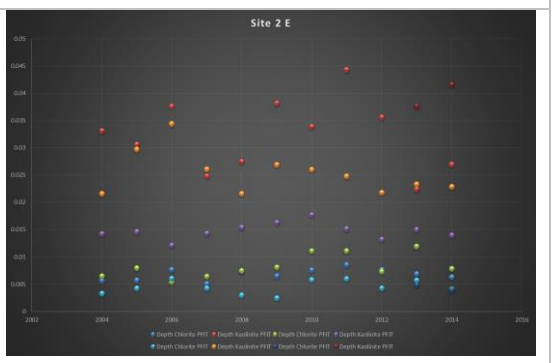

Site 2 B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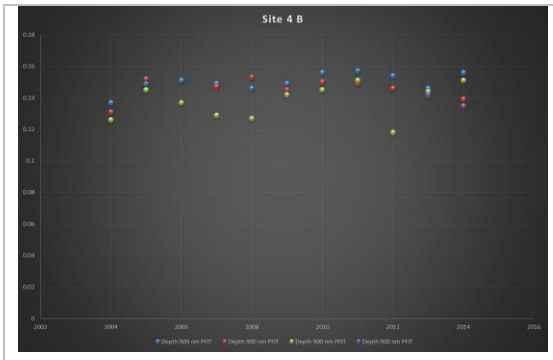
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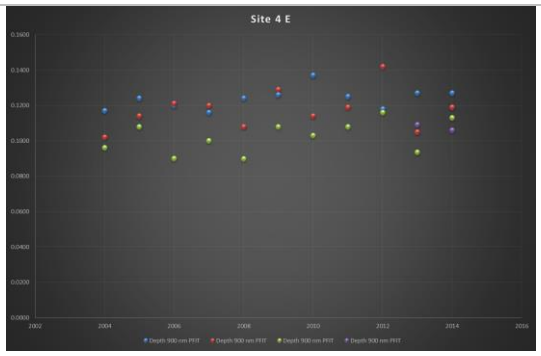
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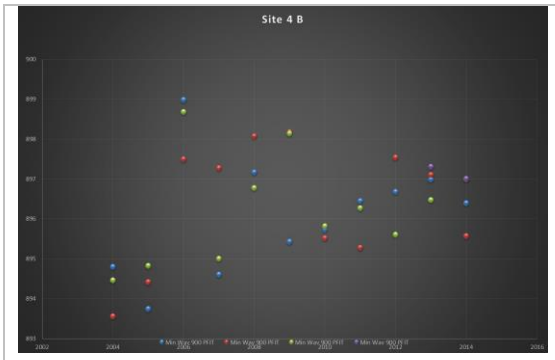
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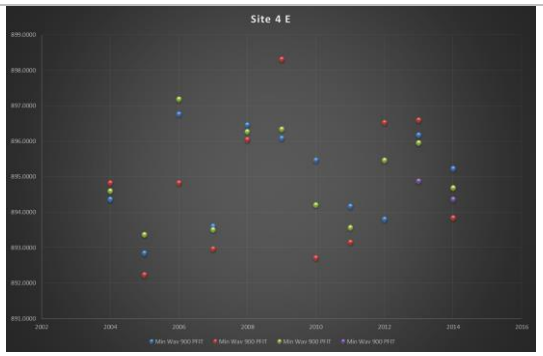
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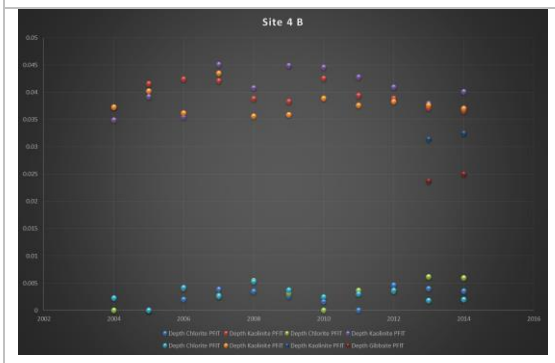
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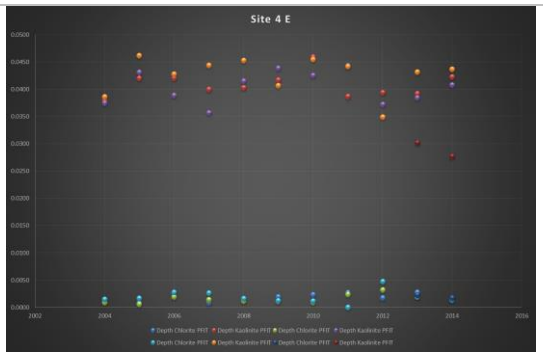
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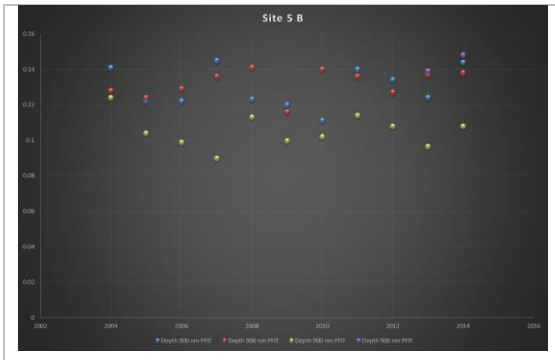
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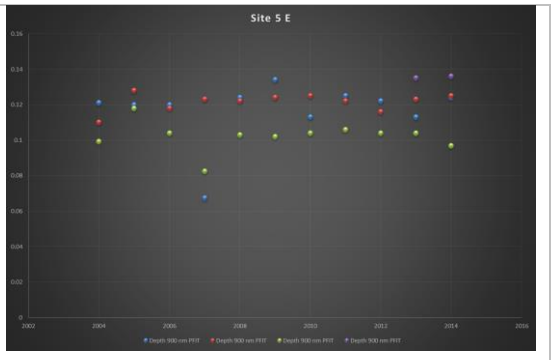
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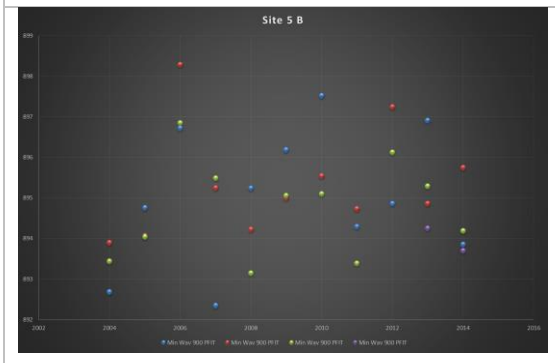
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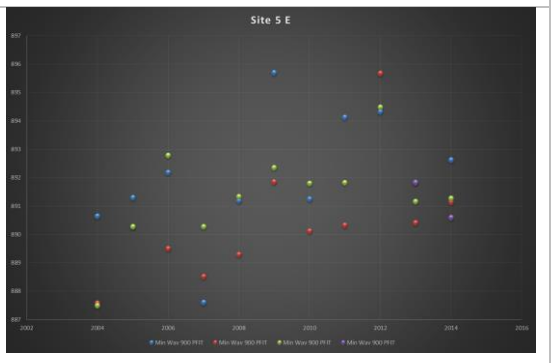
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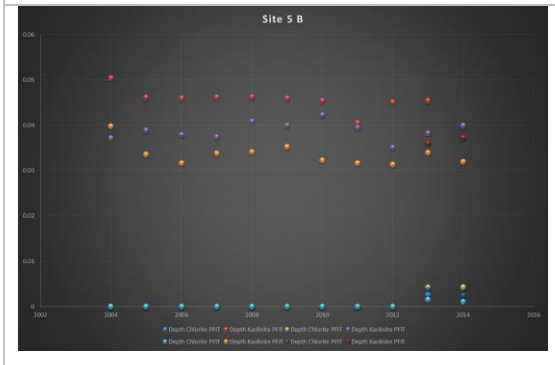
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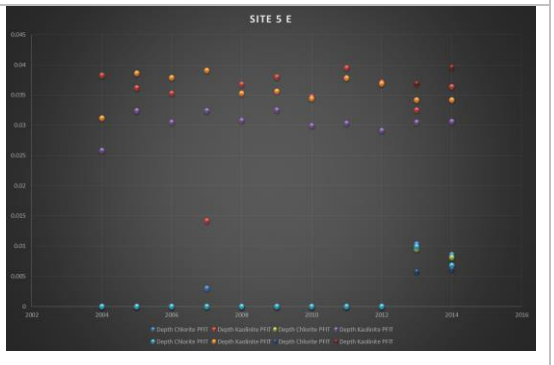
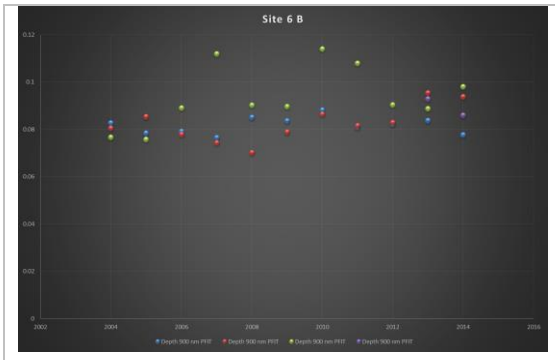
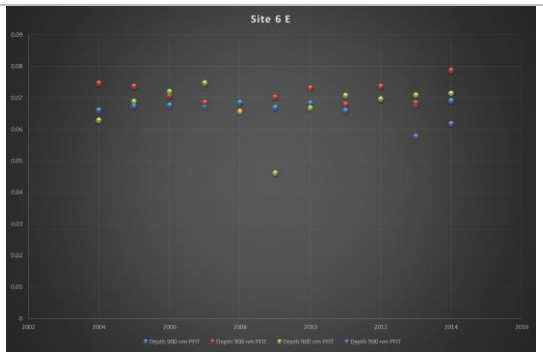

SITE 5 E


Site 6 B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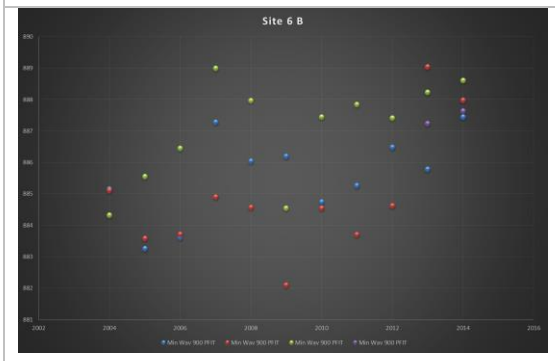
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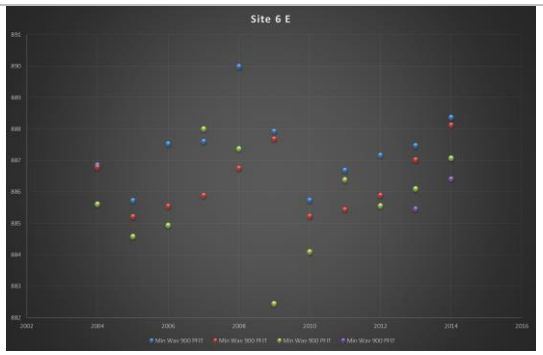
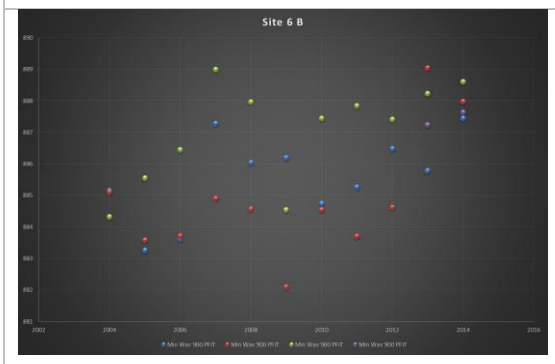
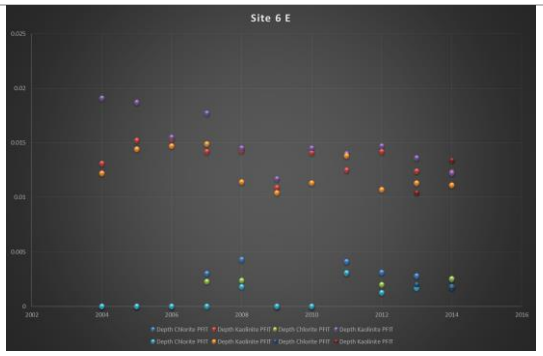
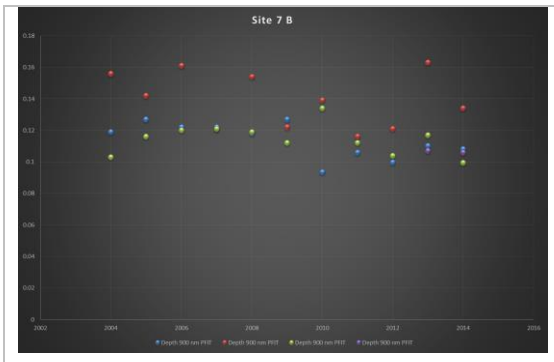
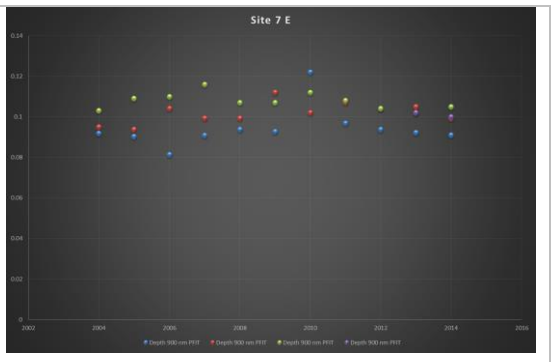
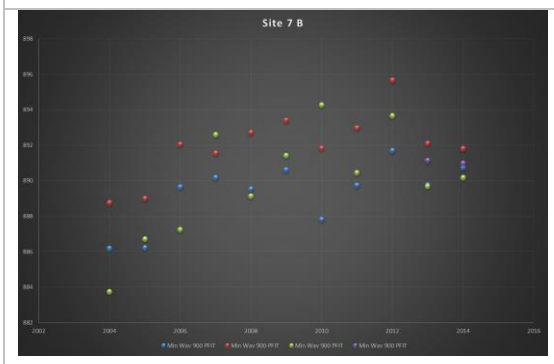

Site 6 E

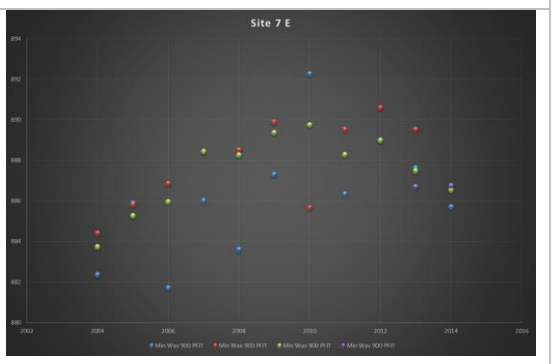

Site 6 B


Site 6 E


Site 7 B


Site 7 E


Site 7 B


Site 7 E

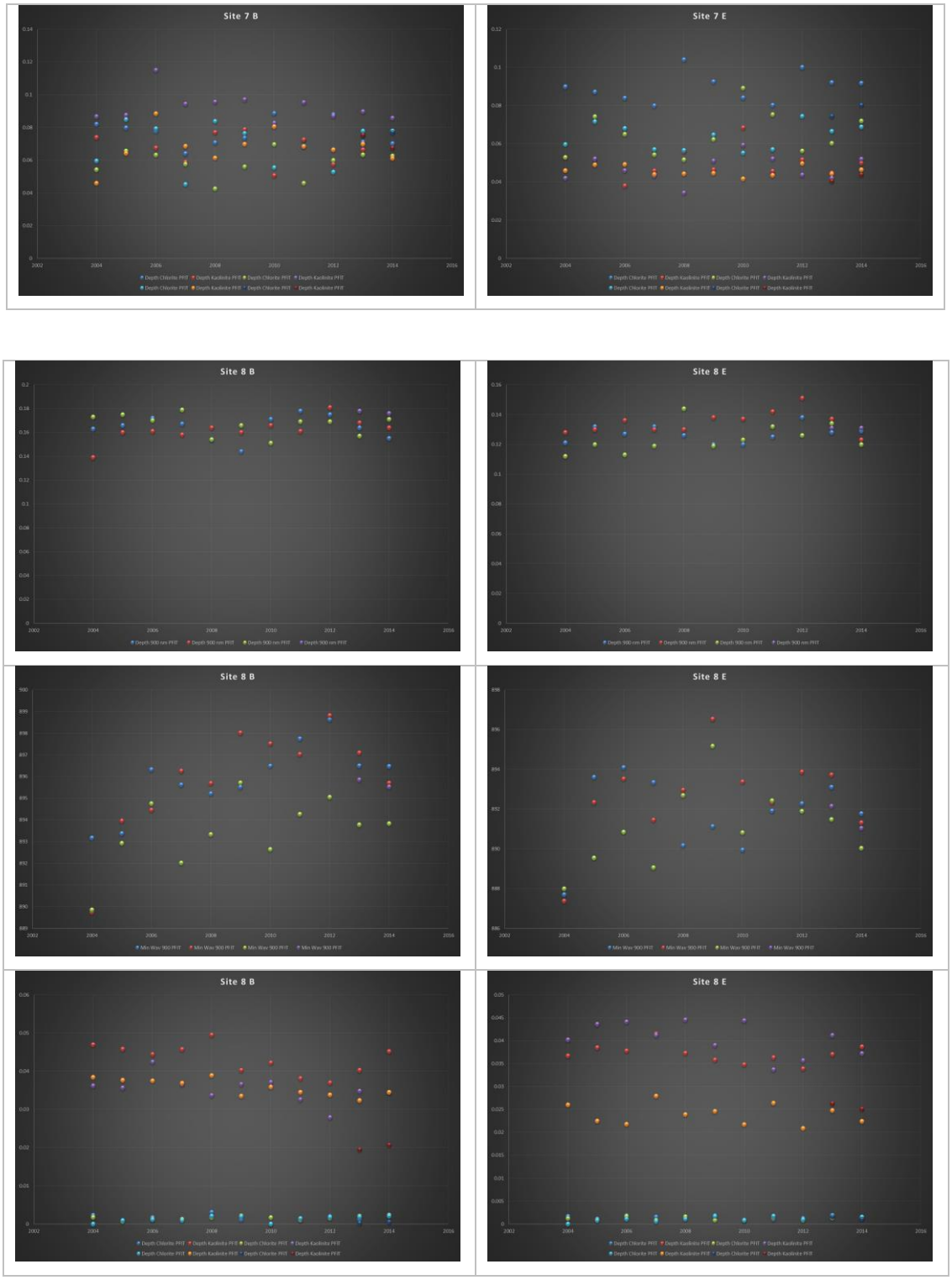


Figure 41. Spectral parameters for all sites

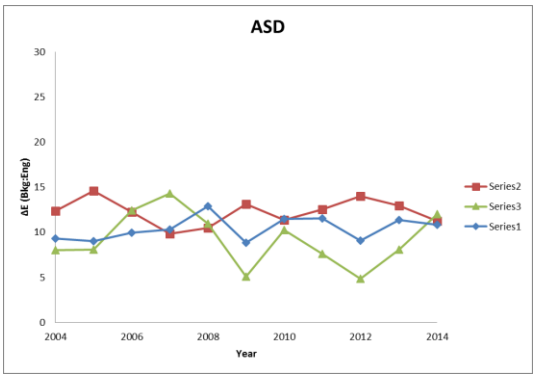
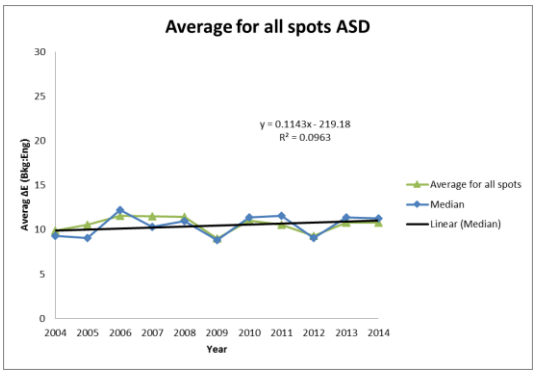
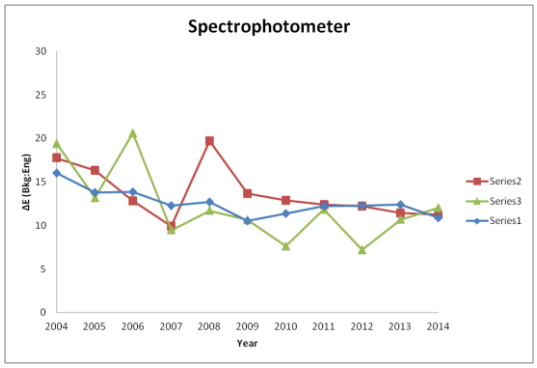
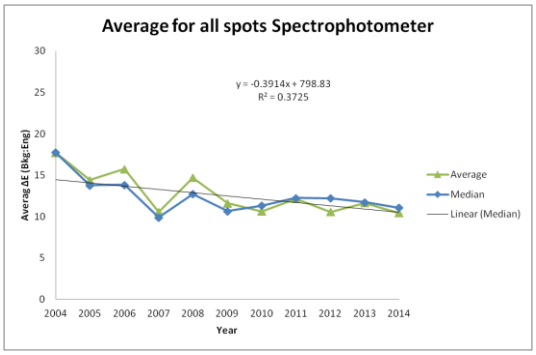
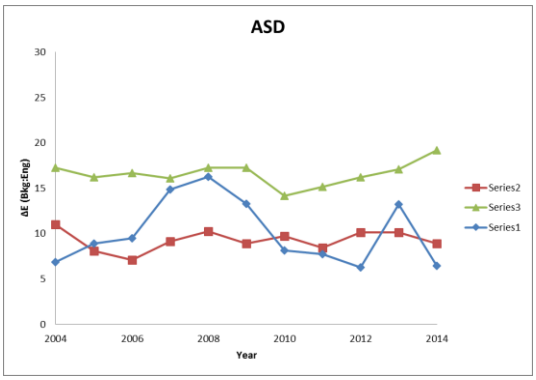
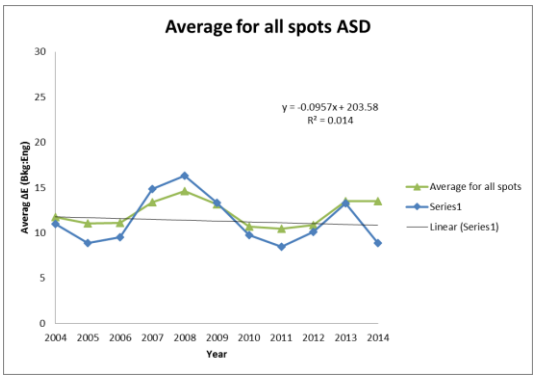
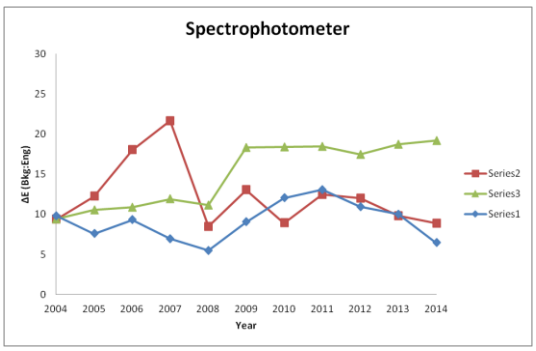
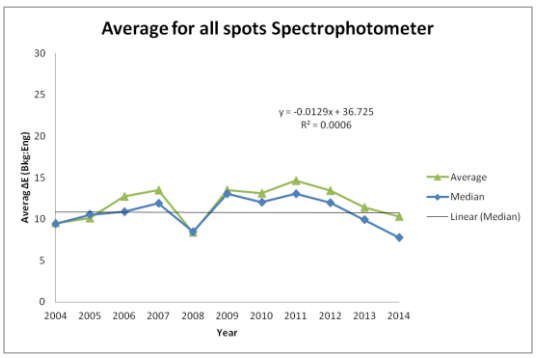
6.2.4 RESULTS FROM THE SPECTRAL PARAMETERS

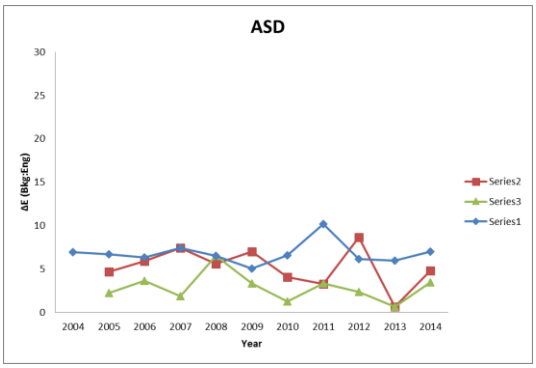
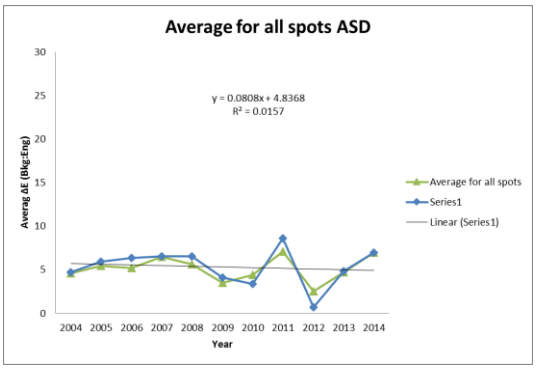
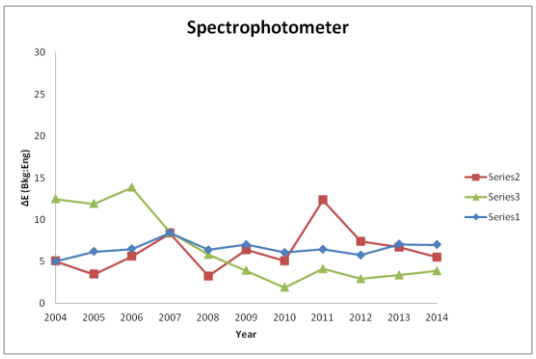
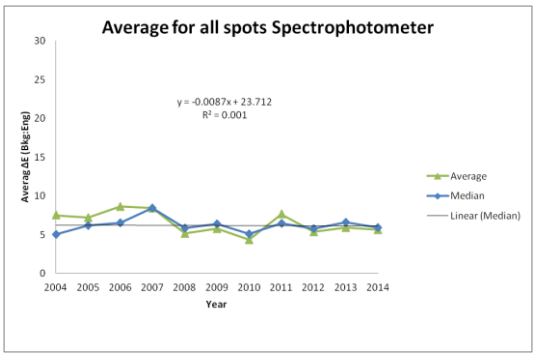
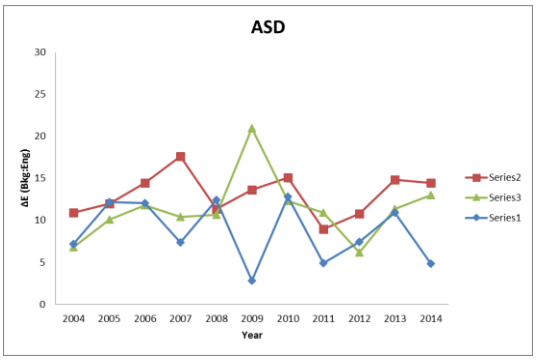
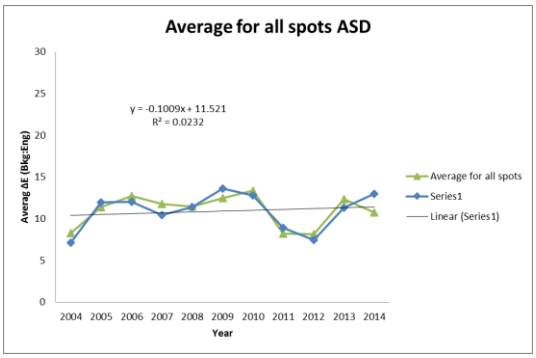
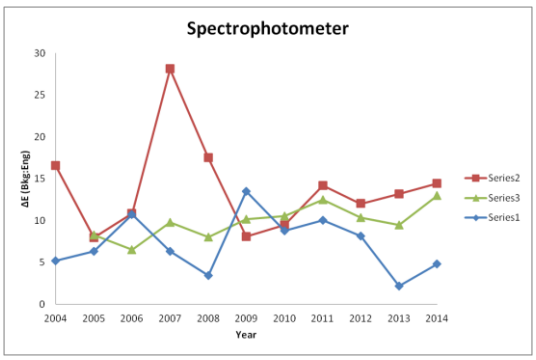
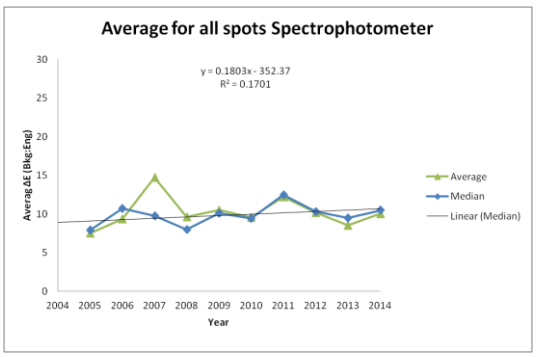
The spectral parameters extracted from the reflectance spectra of all sites and, all backgrounds and engravings, combined with the statistical analysis show that there no systematic changes in any of the site. The comparison was not prepared for Site 21, 22 and 23 as there are only 2 points.

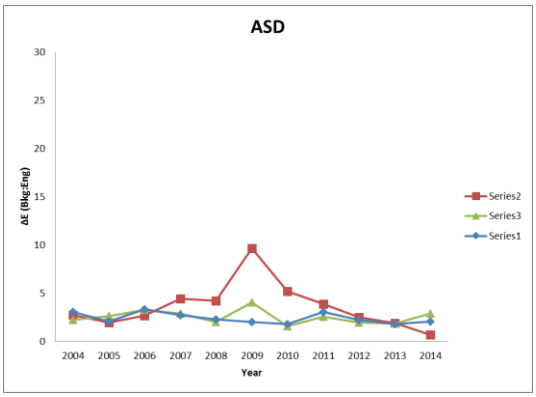
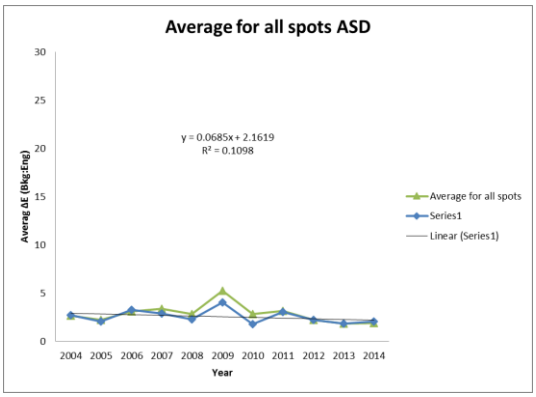
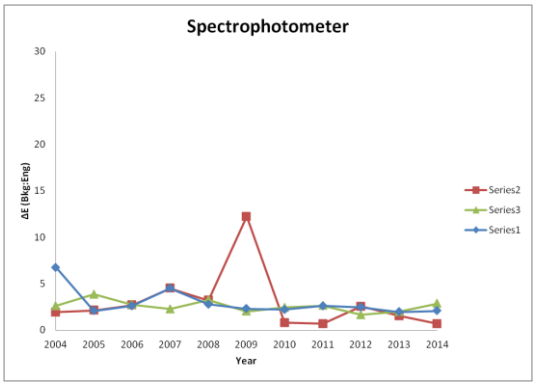
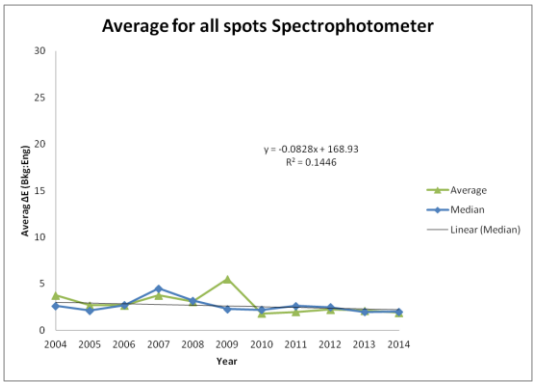
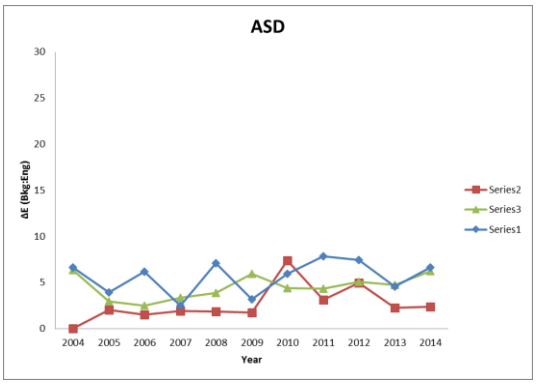
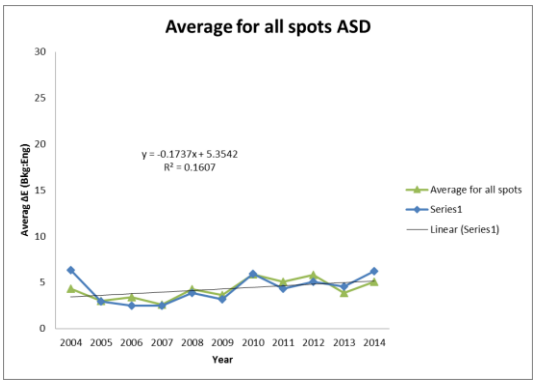
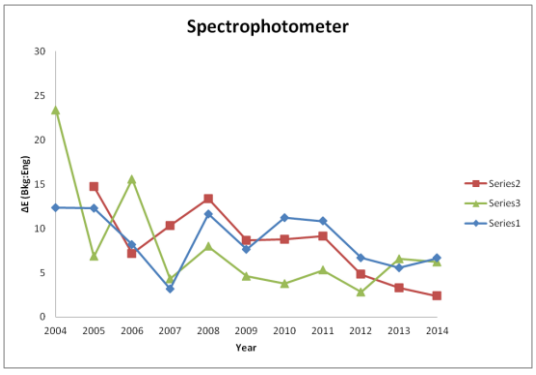
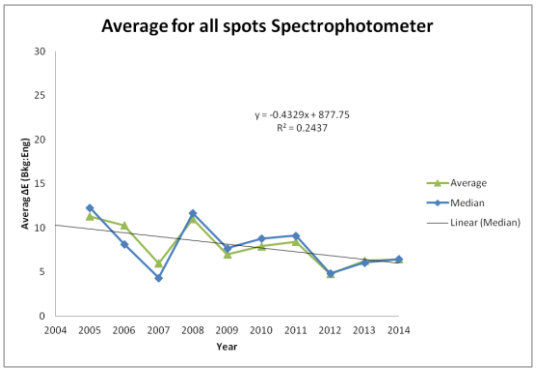
7. Comparison between spectrophotometer and ASD for the colour difference between the background and engraving

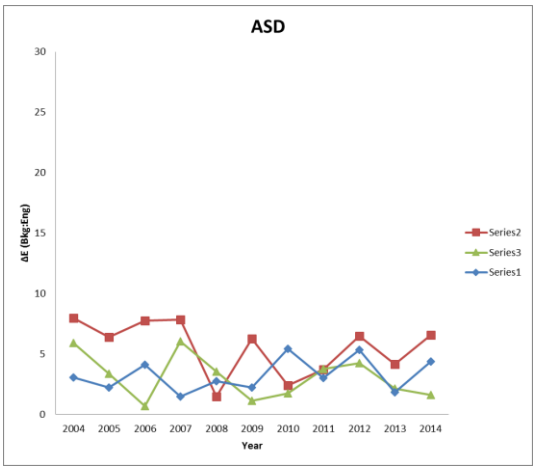
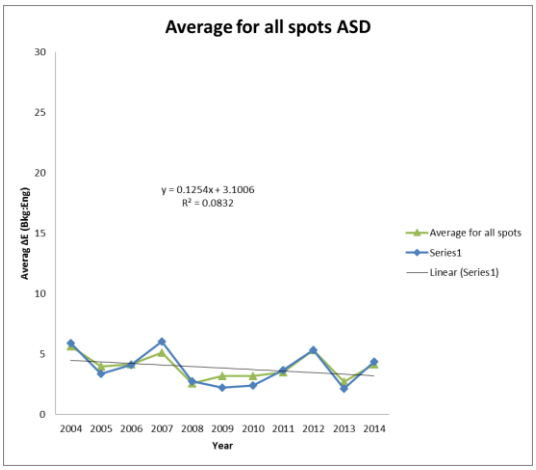
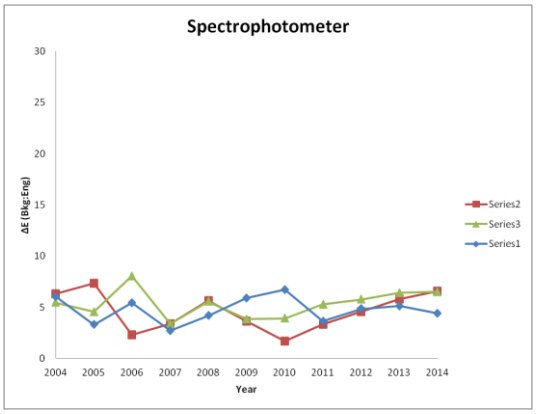
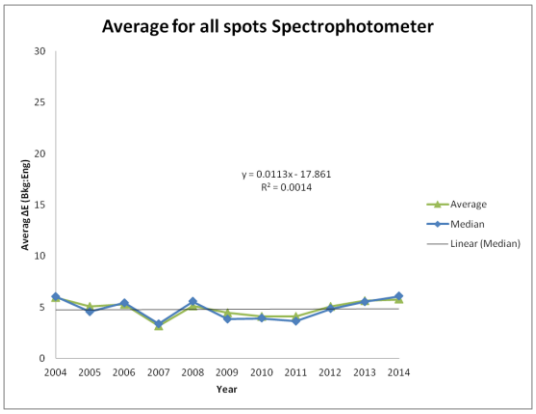
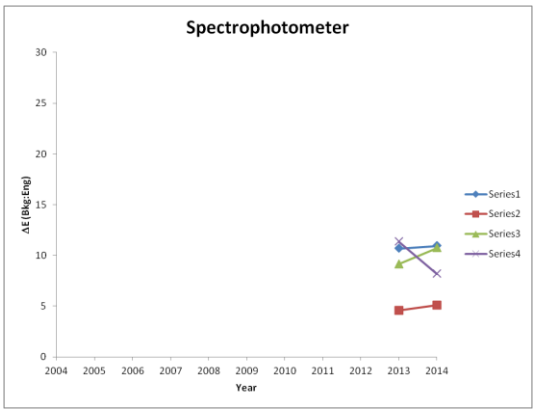
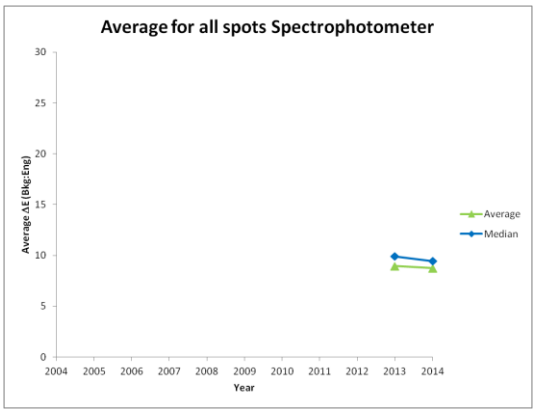
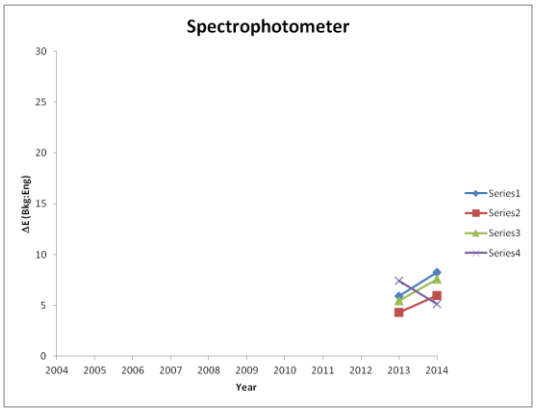
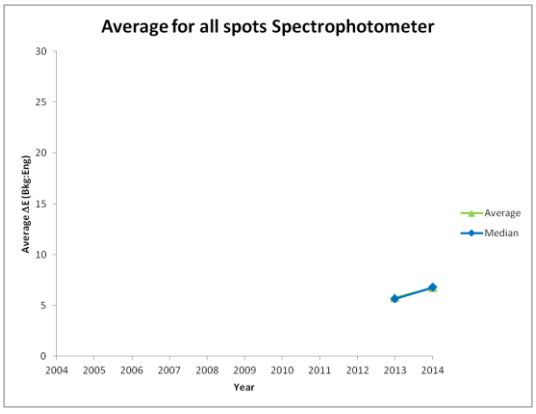
The comparison of the colour difference between engravings and background using the ASD and spectrophotometer at all sites are shown in Figure 42. In most cases, the average ΔE values obtained from each of the techniques are comparable, and the gradients of the linear fit of the average data show good 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.

Site	Colour variation per spot	Average colour variation
Site 1 Dolphin Island		
		
Site 2 Gidley Island		
		

Site 4 Wood side		
		
Site 5 Burrup Rd		
		

Site 6 Water Tanks		
		
Site 7 Deep Gorge		
		

Site 8 King Bay South		
		
Site 21 Yara West		
Site 22 Yara North East		

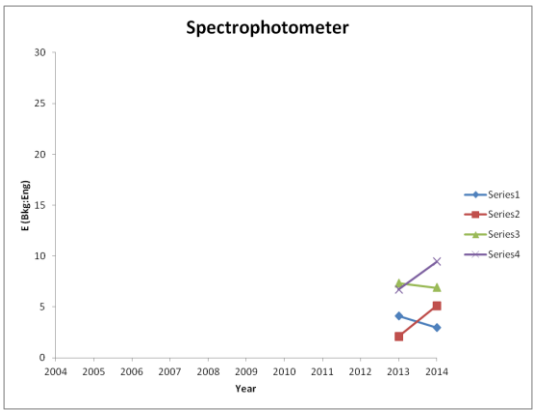
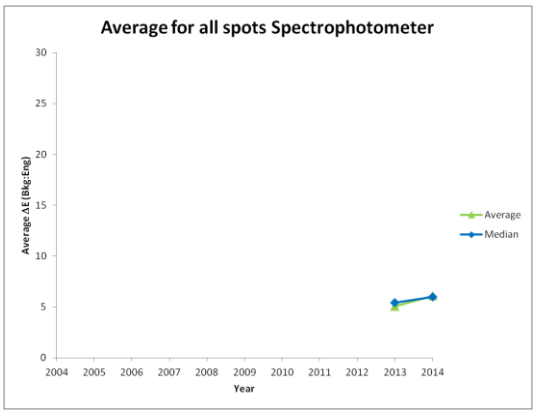
Site 23 Yara East		

Figure 42: ASD reflectance spectrometer and colour measurements for each site, 2004-2014.

8. Conclusion of 2004-2014 study

The petroglyphs at 7 sites in the Burrup Peninsula were measured annually from 2004 to 2014, 3 new sites close to the new Yara construction plant were also added bringing the total to 10 sites. The same engravings and background rocks were measured *in situ*. Measurement of the annual colour changes utilised two spectrophotometer techniques, the spectroradiometer Analytical Spectral Device or ASD and two colour spectrophotometers; the BYK and Olympus. 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 second time and showed that none of the engravings or background showed systematic change through time.

9. References

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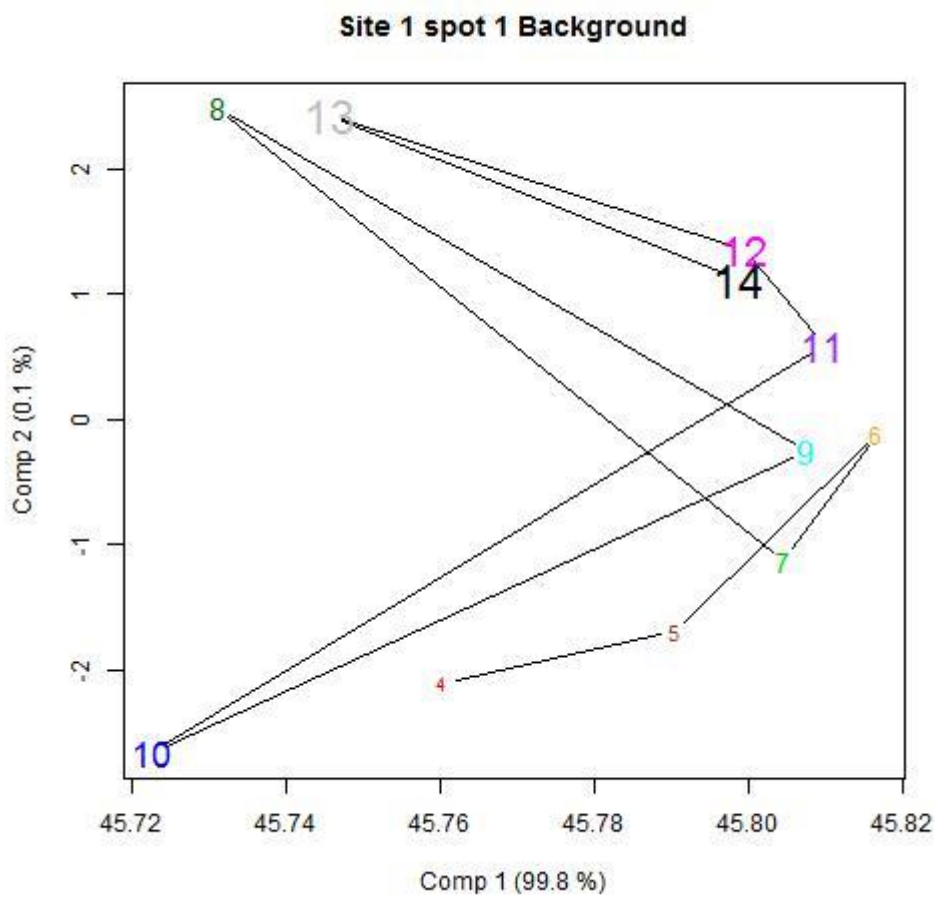
Appendix A



[1] Site 1 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0000119	0.00001188	0.0082	0.9303
I((4:14)^2)	1	0.0000223	0.00002232	0.0153	0.9045
Residuals	8	0.0116533	0.00145666		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

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

1 10 0.011687

2 8 0.011653 2 3.4201e-05 0.0117 0.9883

[1] Site 1 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

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

I(4:14) 1 11.3124 11.3124 4.5500 0.06548 .

I((4:14)^2) 1 0.0231 0.0231 0.0093 0.92566

Residuals 8 19.8898 2.4862

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Analysis of Variance Table

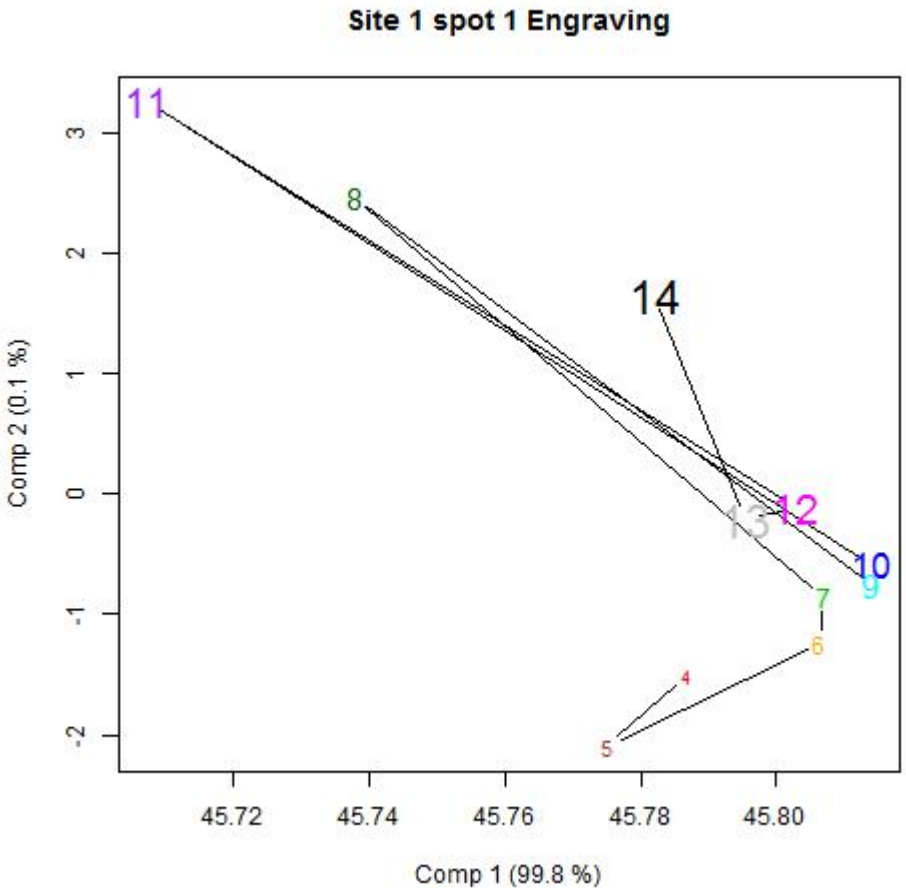
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

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

1 10 31.225

2 8 19.890 2 11.335 2.2797 0.1646



[1] Site 1 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0000536	0.00005360	0.0381	0.8502
I((4:14)^2)	1	0.0000283	0.00002827	0.0201	0.8908
Residuals	8	0.0112668	0.00140835		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.011349				
2	8	0.011267	2	8.1868e-05	0.0291	0.9715

[1] Site 1 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	9.2410	9.2410	3.9639	0.08165 .
I((4:14)^2)	1	1.3498	1.3498	0.5790	0.46855
Residuals	8	18.6506	2.3313		

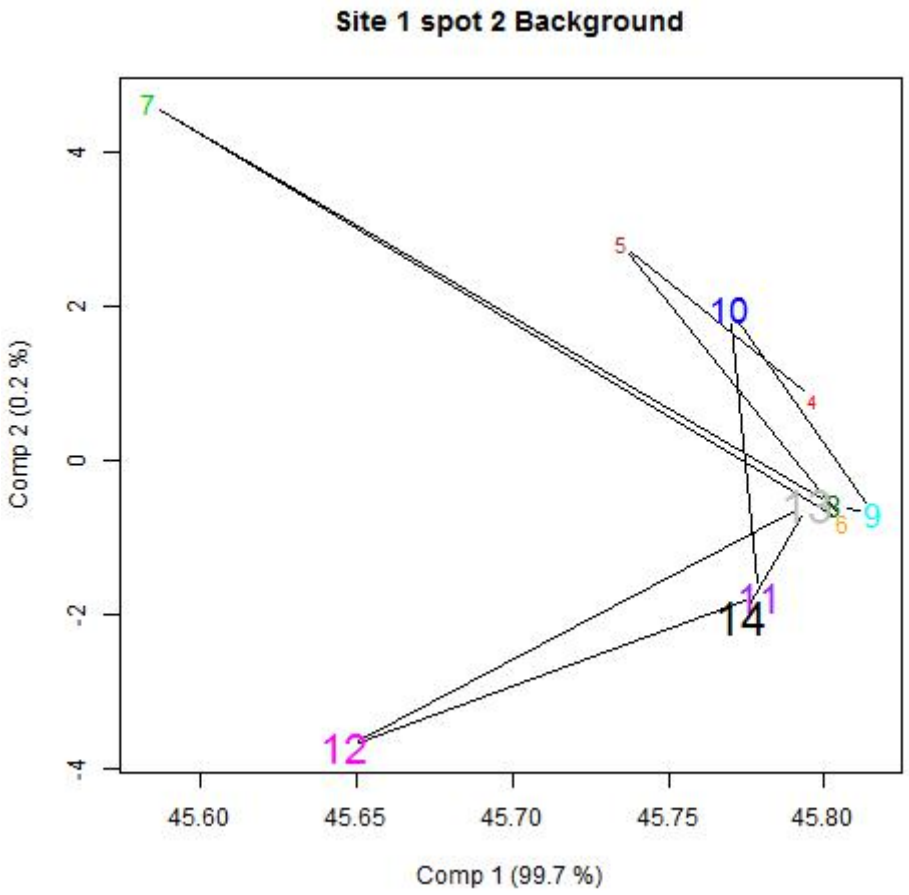
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	29.241			
2	8	18.651	2	10.591	2.2714 0.1655



[1] Site 1 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000000	0.0000001	0.0000	0.9979
I((4:14)^2)	1	0.000739	0.0007394	0.1094	0.7493
Residuals	8	0.054046	0.0067558		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.054786			
2	8	0.054046	2	0.00073945	0.0547	0.9471

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	19.777	19.7772	4.3652	0.07009	.
I((4:14)^2)	1	0.639	0.6395	0.1411	0.71691	
Residuals	8	36.245	4.5307			

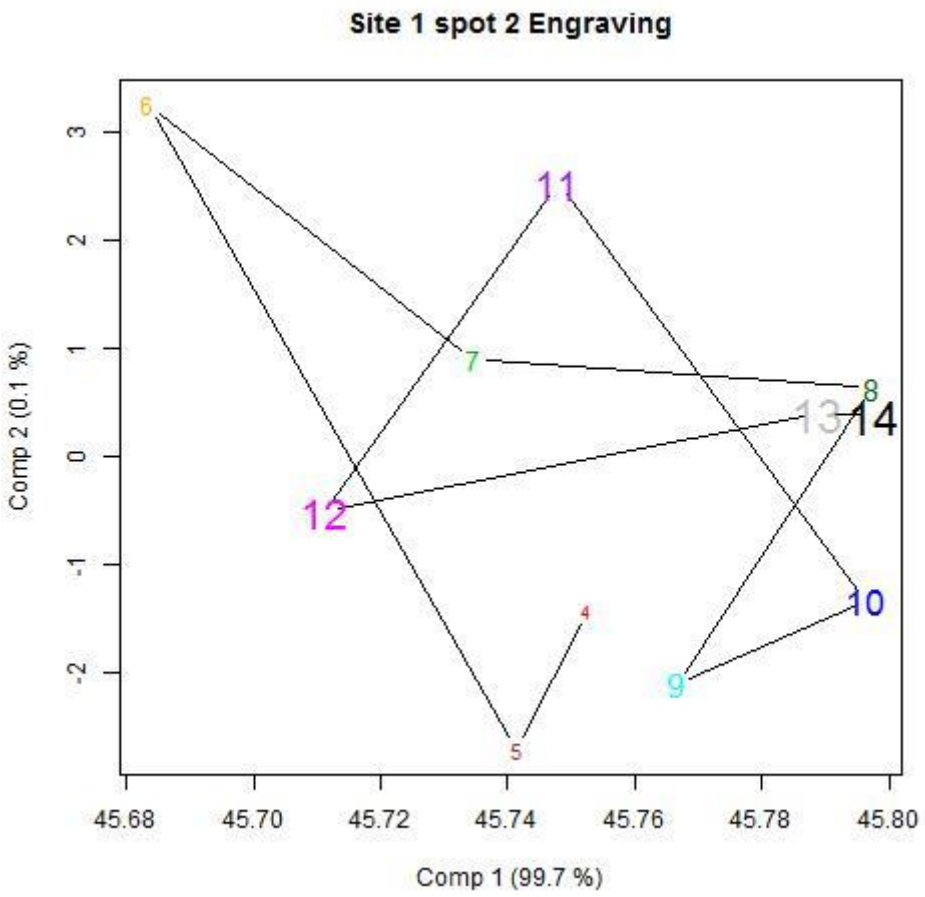
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	56.662			
2	8	36.245	2	20.417	2.2532	0.1674



[1] Site 1 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0024939	0.00249393	1.6945	0.2292
I((4:14)^2)	1	0.0000198	0.00001984	0.0135	0.9104
Residuals	8	0.0117743	0.00147178		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.014288				
2	8	0.011774	2	0.0025138	0.854	0.4612

[1] Site 1 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

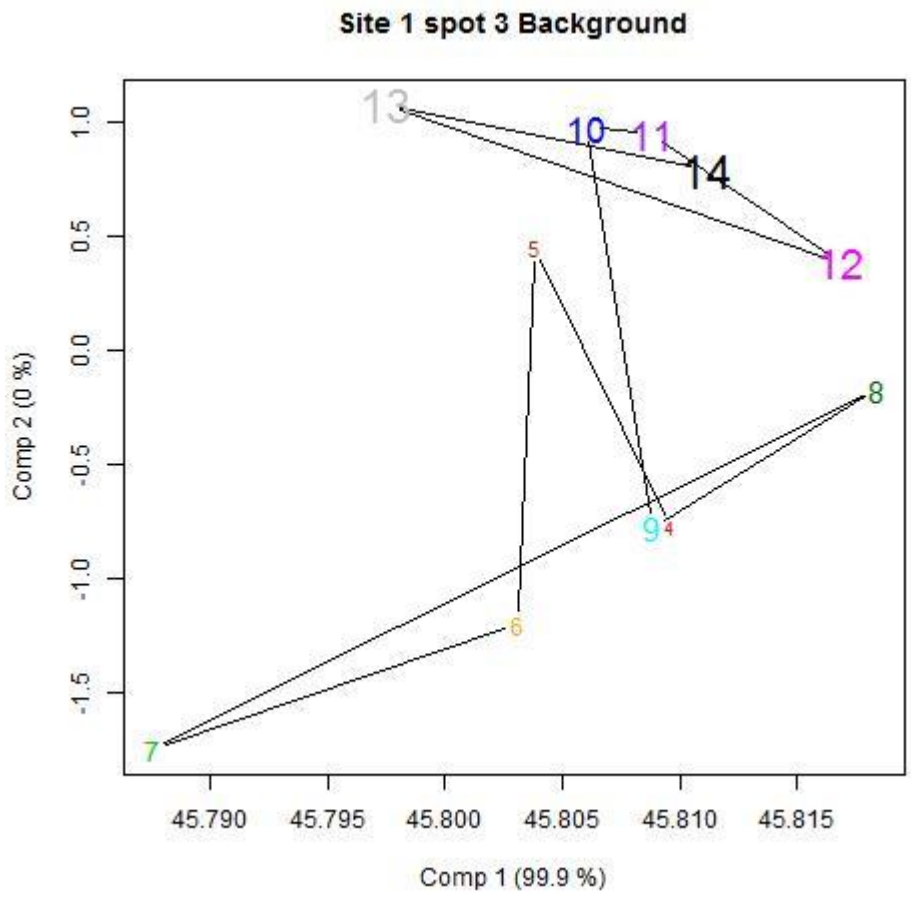
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	1.185	1.1846	0.2933	0.6028
I((4:14)^2)	1	0.761	0.7609	0.1884	0.6757
Residuals	8	32.309	4.0386		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	34.254				
2	8	32.309	2	1.9455	0.2409	0.7914



[1] Site 1 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.00002614	2.6141e-05	0.2897	0.6051
I((4:14)^2)	1	0.00000018	1.8100e-07	0.0020	0.9654
Residuals	8	0.00072199	9.0248e-05		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.00074831				
2	8	0.00072199	2	2.6322e-05	0.1458	0.8665

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:14)	1	4.2425	4.2425	6.5535	0.03365	*
I((4:14)^2)	1	0.2848	0.2848	0.4399	0.52583	
Residuals	8	5.1790	0.6474			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

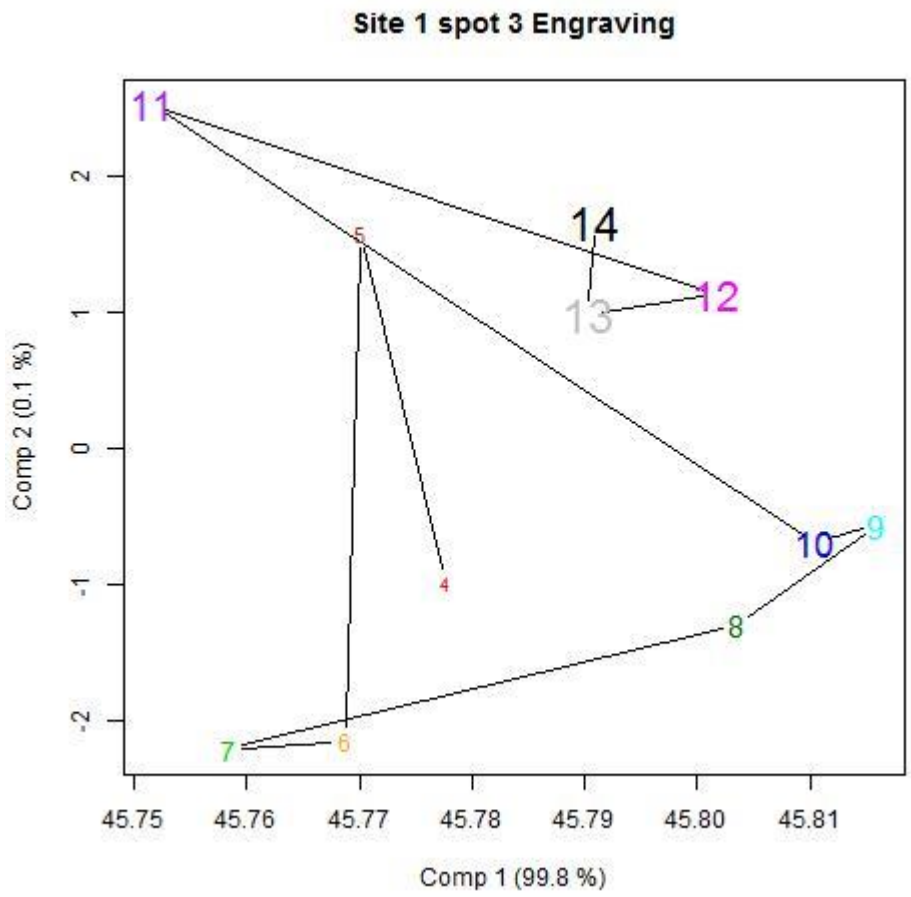
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	9.7062				
2	8	5.1790	2	4.5273	3.4967	0.08105 .

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1



[1] Site 1 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0005200	0.00051999	1.0599	0.3334
I((4:14)^2)	1	0.0002085	0.00020854	0.4251	0.5327
Residuals	8	0.0039247	0.00049059		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.0046532				
2	8	0.0039247	2	0.00072853	0.7425	0.5061

[1] Site 1 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	8.6692	8.6692	4.4667	0.06751 .
I((4:14)^2)	1	2.7214	2.7214	1.4022	0.27035
Residuals	8	15.5267	1.9408		

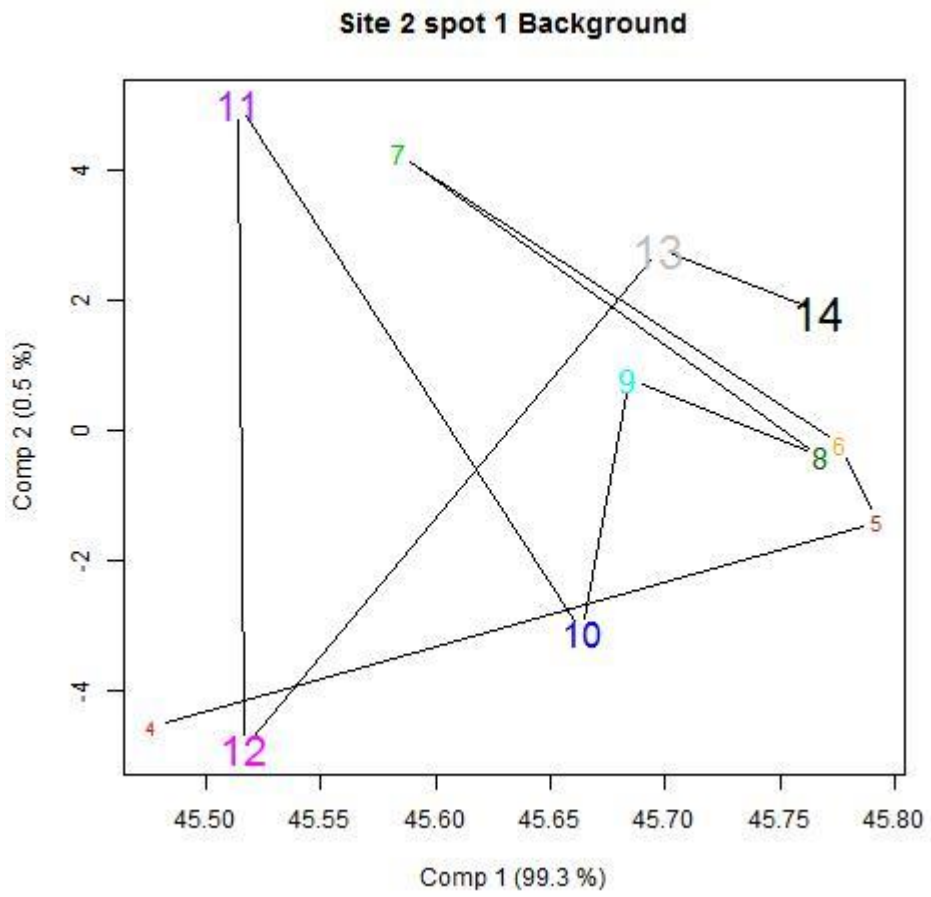
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	26.917			
2	8	15.527	2	11.391	2.9345 0.1107



[1] Site 2 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000025	0.0000247	0.0014	0.9707
I((4:14)^2)	1	0.000000	0.0000001	0.0000	0.9981
Residuals	8	0.137608	0.0172010		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.13763				
2	8	0.13761	2	2.4821e-05	7e-04	0.9993

[1] Site 2 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

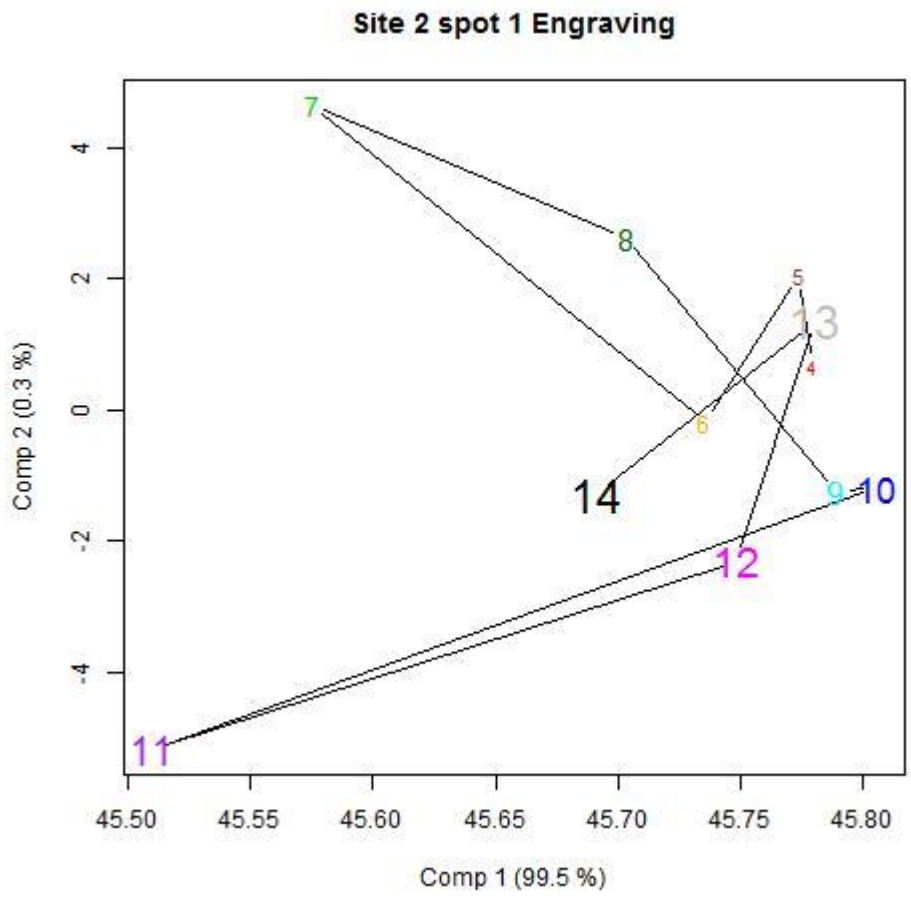
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	10.150	10.1502	0.8383	0.3866
I((4:14)^2)	1	4.118	4.1177	0.3401	0.5758
Residuals	8	96.865	12.1081		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	111.132				
2	8	96.865	2	14.268	0.5892	0.5772



[1] Site 2 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.001476	0.0014759	0.1416	0.7165
I((4:14)^2)	1	0.004301	0.0043009	0.4125	0.5387
Residuals	8	0.083407	0.0104258		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.089183				
2	8	0.083407	2	0.0057768	0.277	0.765

[1] Site 2 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

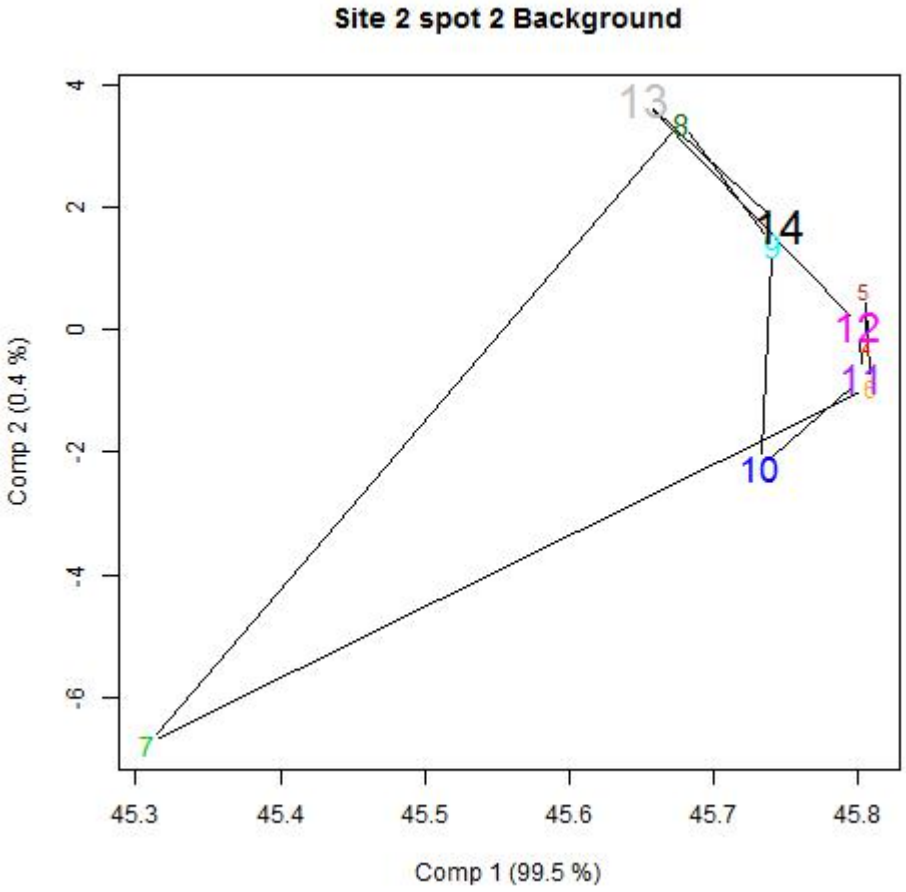
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	16.250	16.2495	2.3569	0.1633
I((4:14)^2)	1	0.308	0.3084	0.0447	0.8378
Residuals	8	55.155	6.8944		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	71.713				
2	8	55.155	2	16.558	1.2008	0.3499



[1] Site 2 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000106	0.000106	0.0043	0.9494
I((4:14)^2)	1	0.015538	0.015538	0.6289	0.4506
Residuals	8	0.197654	0.024707		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.21330			
2	8	0.19765	2	0.015644	0.3166 0.7373

[1] Site 2 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

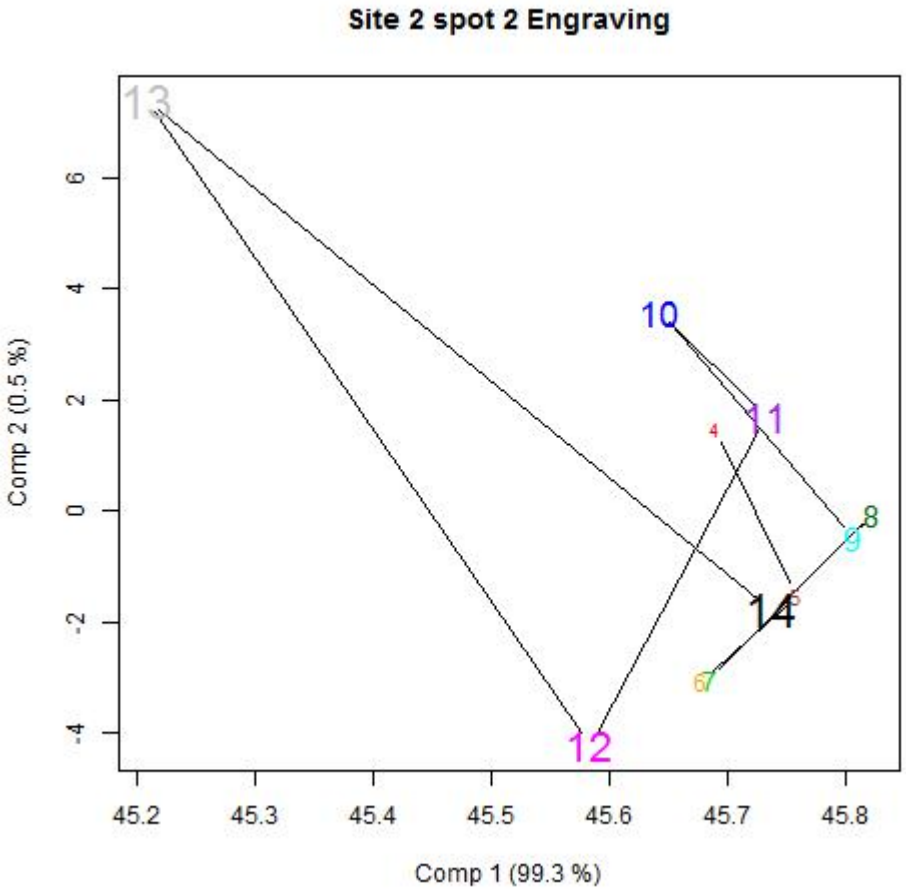
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	9.128	9.1276	1.0688	0.3315
I((4:14)^2)	1	5.702	5.7022	0.6677	0.4375
Residuals	8	68.323	8.5403		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	83.152				
2	8	68.323	2	14.83	0.8682	0.4558



[1] Site 2 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.049522	0.049522	1.8578	0.210
I((4:14)^2)	1	0.016892	0.016892	0.6337	0.449
Residuals	8	0.213246	0.026656		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.27966				
2	8	0.21325	2	0.066414	1.2458	0.3381

[1] Site 2 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

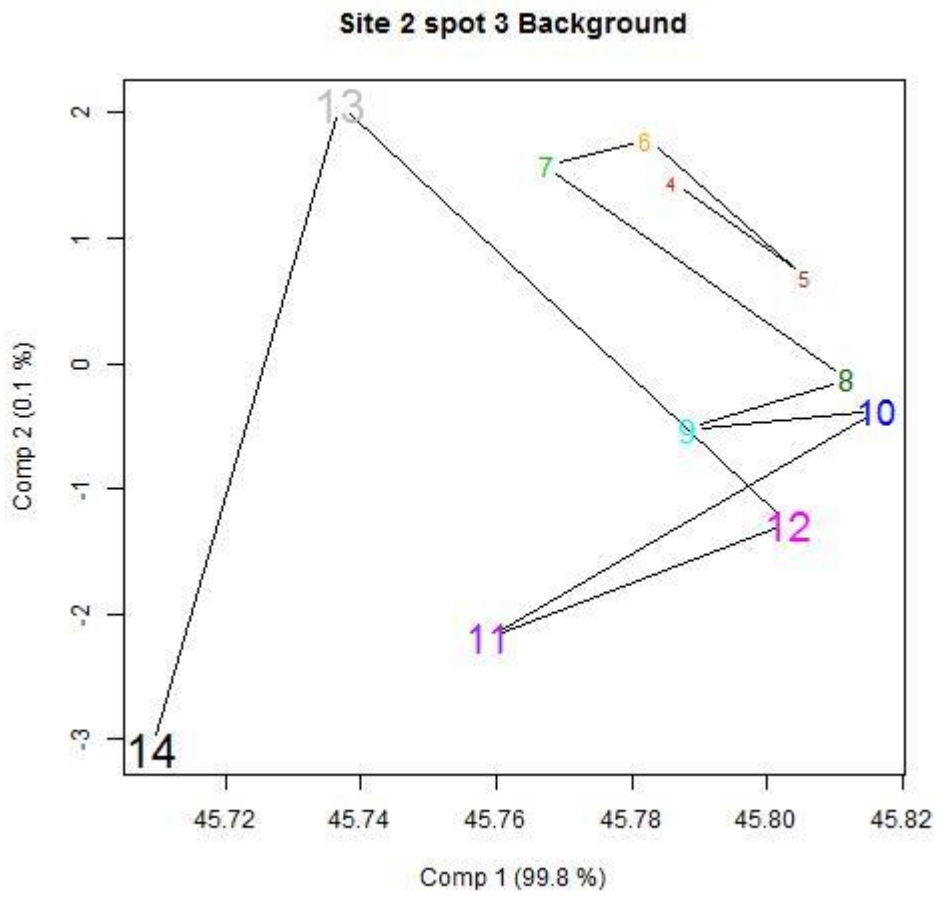
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	7.651	7.6510	0.5763	0.4695
I((4:14)^2)	1	0.411	0.4112	0.0310	0.8647
Residuals	8	106.200	13.2750		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	114.26				
2	8	106.20	2	8.0622	0.3037	0.7463



[1] Site 2 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:14)	1	0.0033707	0.0033707	5.6718	0.04444	*
I((4:14)^2)	1	0.0029532	0.0029532	4.9694	0.05637	.
Residuals	8	0.0047543	0.0005943			

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(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.0110782				
2	8	0.0047543	2	0.0063239	5.3206	0.03392 *

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

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	10.5591	10.5591	4.6328	0.06354 .
I((4:14)^2)	1	0.0276	0.0276	0.0121	0.91505
Residuals	8	18.2338	2.2792		

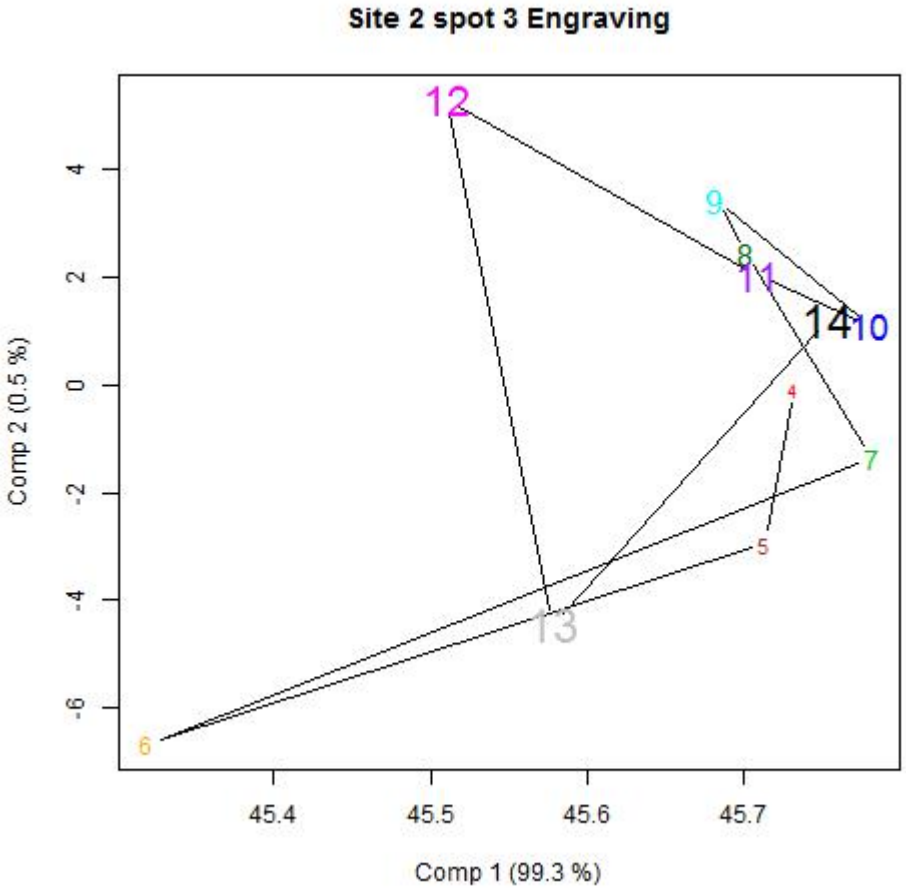
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	28.820				
2	8	18.234	2	10.587	2.3224	0.1602



[1] Site 2 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000052	0.0000524	0.0021	0.9642
I((4:14)^2)	1	0.000013	0.0000130	0.0005	0.9822
Residuals	8	0.195587	0.0244484		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.19565				
2	8	0.19559	2	6.5361e-05	0.0013	0.9987

[1] Site 2 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

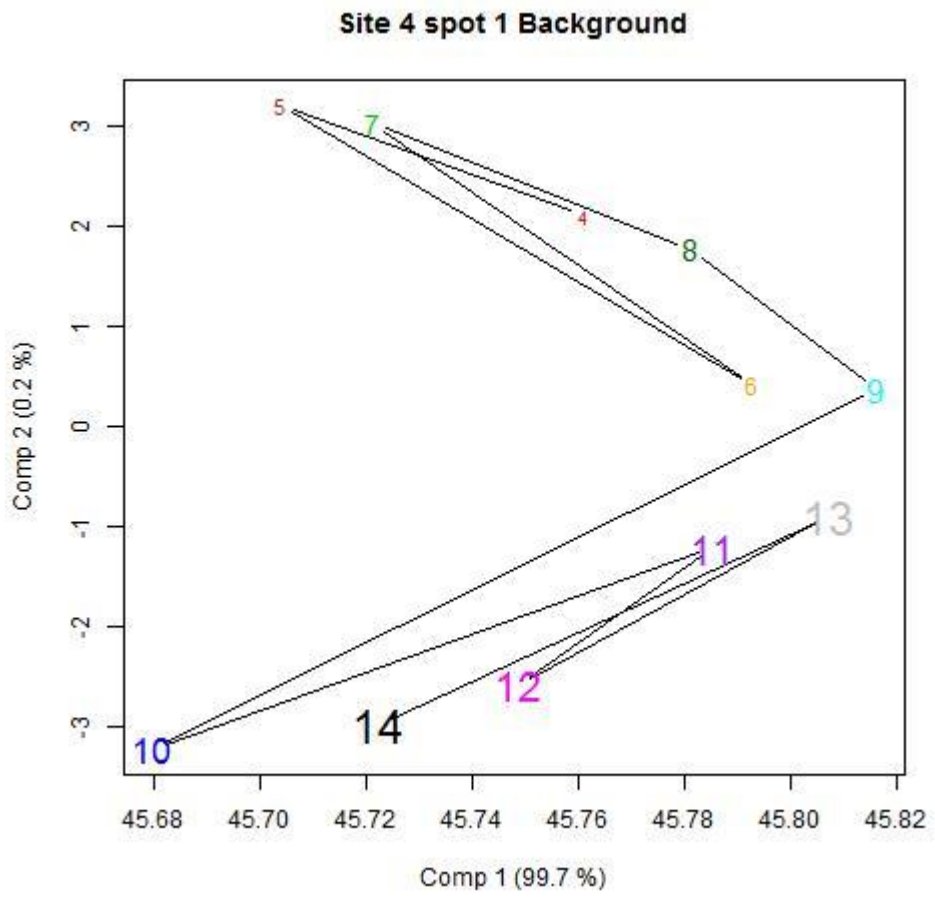
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	15.852	15.852	1.2643	0.2934
I((4:14)^2)	1	10.846	10.846	0.8650	0.3796
Residuals	8	100.311	12.539		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	127.01				
2	8	100.31	2	26.698	1.0646	0.3891



[1] Site 4 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0001165	0.00011649	0.0475	0.8329
I((4:14)^2)	1	0.0003826	0.00038257	0.1561	0.7031
Residuals	8	0.0196119	0.00245149		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.020111				
2	8	0.019612	2	0.00049906	0.1018	0.9044

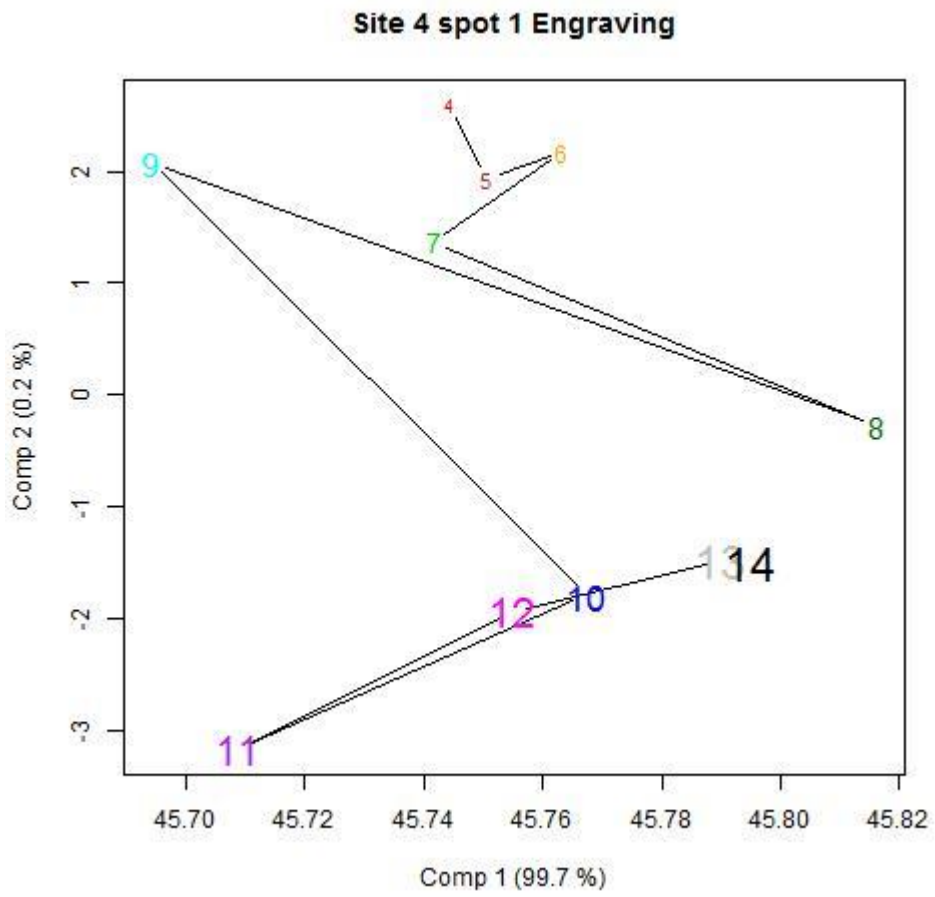
[1] Site 4 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

```
          Df Sum Sq Mean Sq F value   Pr(>F)
I(4:14)      1 37.503  37.503 16.7744 0.003458 **
I((4:14)^2)  1  0.002   0.002  0.0009 0.976482
Residuals    8 17.886   2.236
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F  Pr(>F)
1     10 55.391
2      8 17.886  2    37.505 8.3876 0.01087 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 4 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0006584	0.00065838	0.4702	0.5123
I((4:14)^2)	1	0.0009793	0.00097934	0.6994	0.4273
Residuals	8	0.0112022	0.00140027		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.012840			
2	8	0.011202	2	0.0016377	0.5848	0.5794

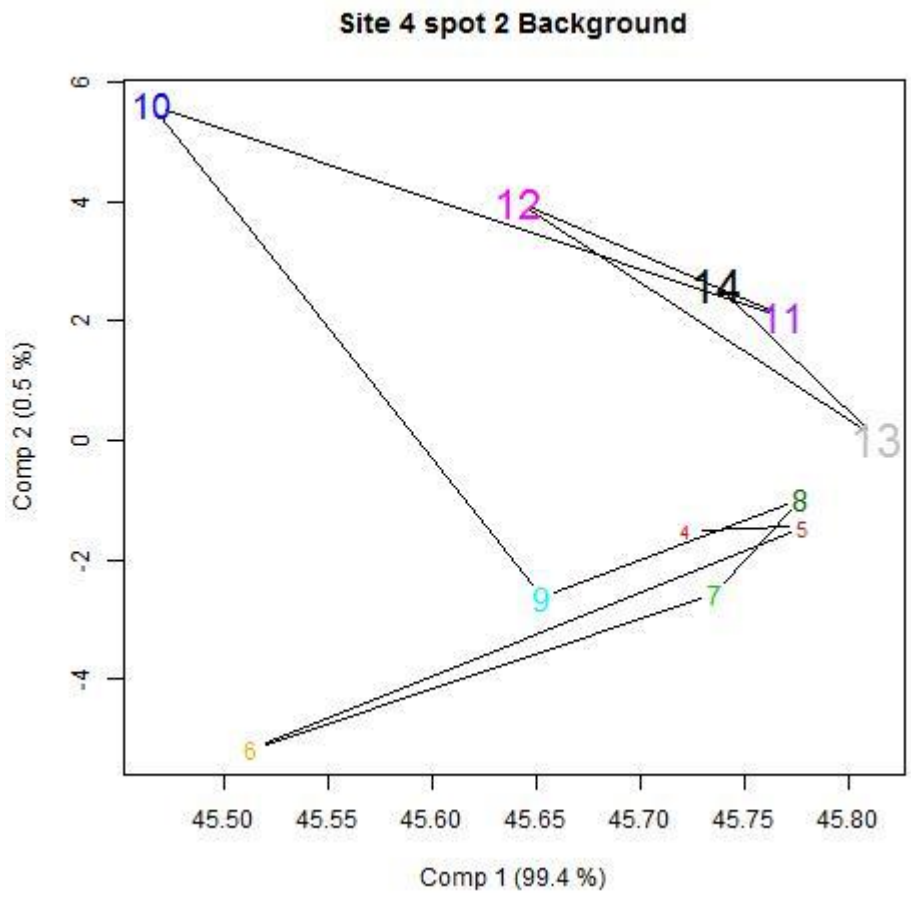
[1] Site 4 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
          Df  Sum Sq Mean Sq F value   Pr(>F)
I(4:14)      1 29.5686 29.5686 19.0261 0.002407 **
I((4:14)^2)  1  0.8881  0.8881  0.5714 0.471357
Residuals    8 12.4329  1.5541
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F   Pr(>F)
1     10 42.890
2      8 12.433  2    30.457 9.7988 0.007061 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 4 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.001098	0.0010978	0.079	0.7858
I((4:14)^2)	1	0.014663	0.0146633	1.055	0.3344
Residuals	8	0.111190	0.0138988		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.12695				
2	8	0.11119	2	0.015761	0.567	0.5885

[1] Site 4 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:14)	1	44.410	44.410	5.9608	0.04047	*
I((4:14)^2)	1	0.012	0.012	0.0016	0.96906	
Residuals	8	59.603	7.450			

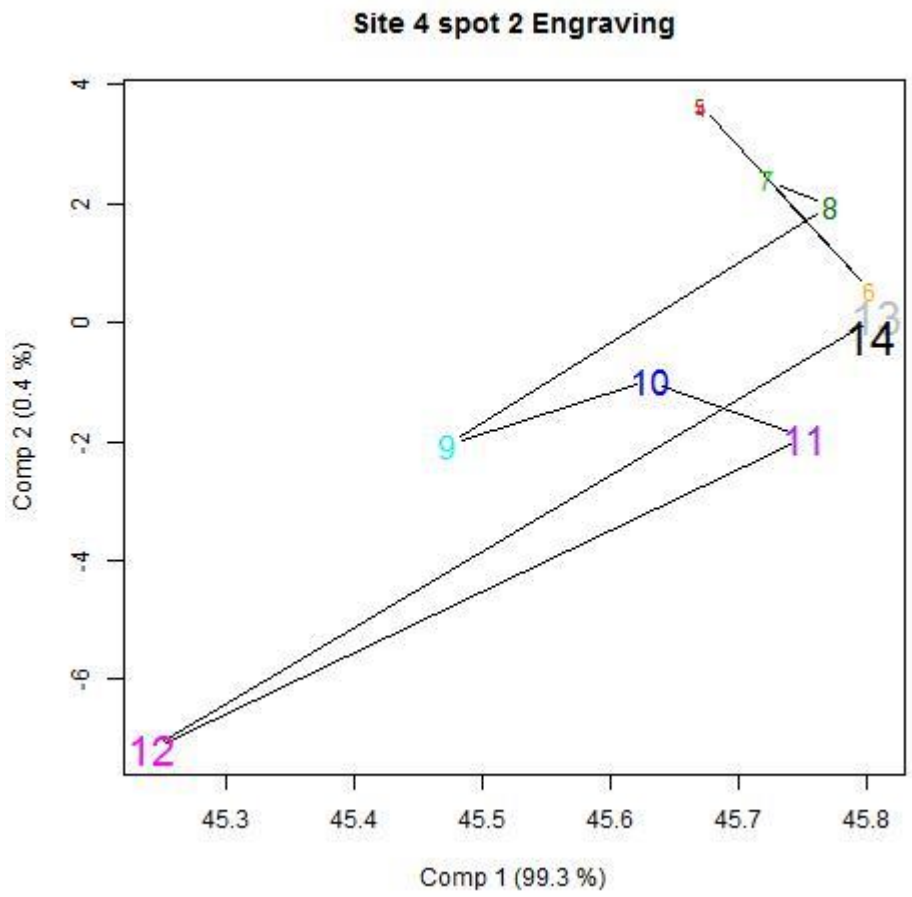
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	104.025				
2	8	59.603	2	44.422	2.9812	0.1078



[1] Site 4 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.002822	0.002822	0.0817	0.7823
I((4:14)^2)	1	0.016502	0.016502	0.4775	0.5091
Residuals	8	0.276464	0.034558		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.29579				
2	8	0.27646	2	0.019324	0.2796	0.7632

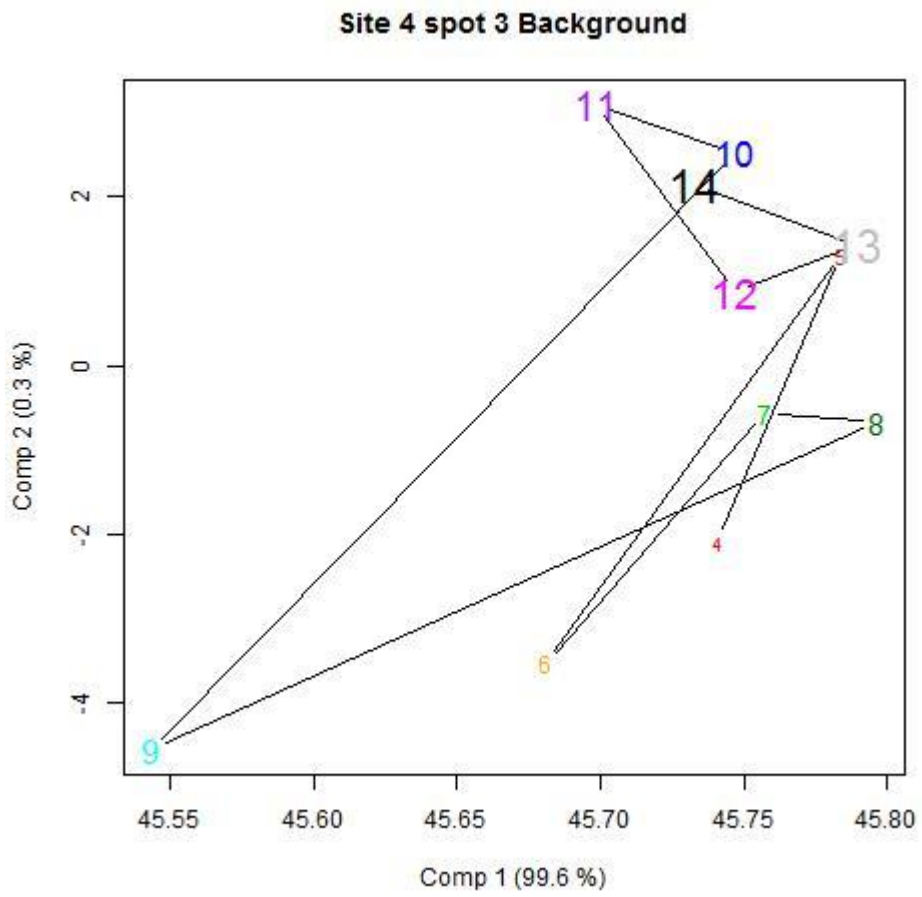
[1] Site 4 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
          Df Sum Sq Mean Sq F value  Pr(>F)
I(4:14)      1 42.229  42.229  7.4637 0.02577 *
I((4:14)^2)  1  9.205   9.205  1.6269 0.23793
Residuals    8 45.263   5.658
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F  Pr(>F)
1     10 96.697
2      8 45.263  2    51.434 4.5453 0.04801 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 4 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000001	0.0000012	0.0002	0.9889
I((4:14)^2)	1	0.004941	0.0049410	0.8738	0.3773
Residuals	8	0.045239	0.0056549		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.050181				
2	8	0.045239	2	0.0049422	0.437	0.6605

[1] Site 4 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	18.710	18.7098	3.4586	0.09997 .
I((4:14)^2)	1	1.316	1.3161	0.2433	0.63510
Residuals	8	43.278	5.4097		

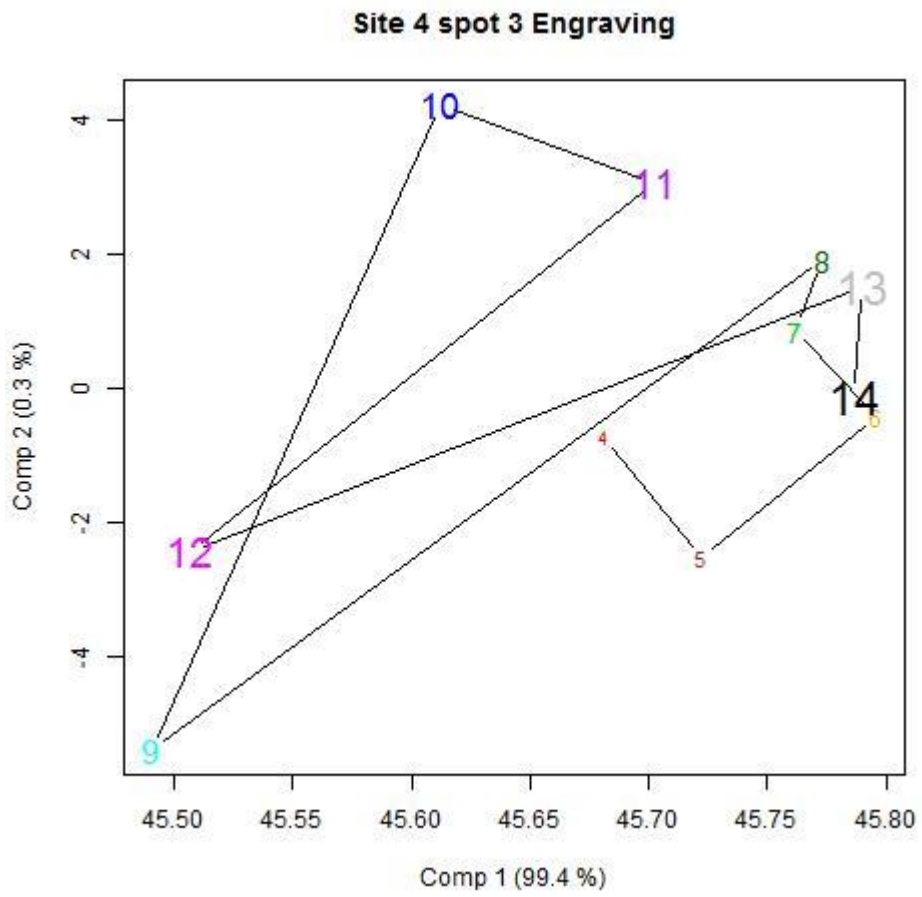
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	63.303			
2	8	43.278	2	20.026	1.8509 0.2184



[1] Site 4 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.001102	0.0011018	0.0828	0.7809
I((4:14)^2)	1	0.015281	0.0152809	1.1479	0.3152
Residuals	8	0.106493	0.0133116		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.12288				
2	8	0.10649	2	0.016383	0.6154	0.5642

[1] Site 4 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

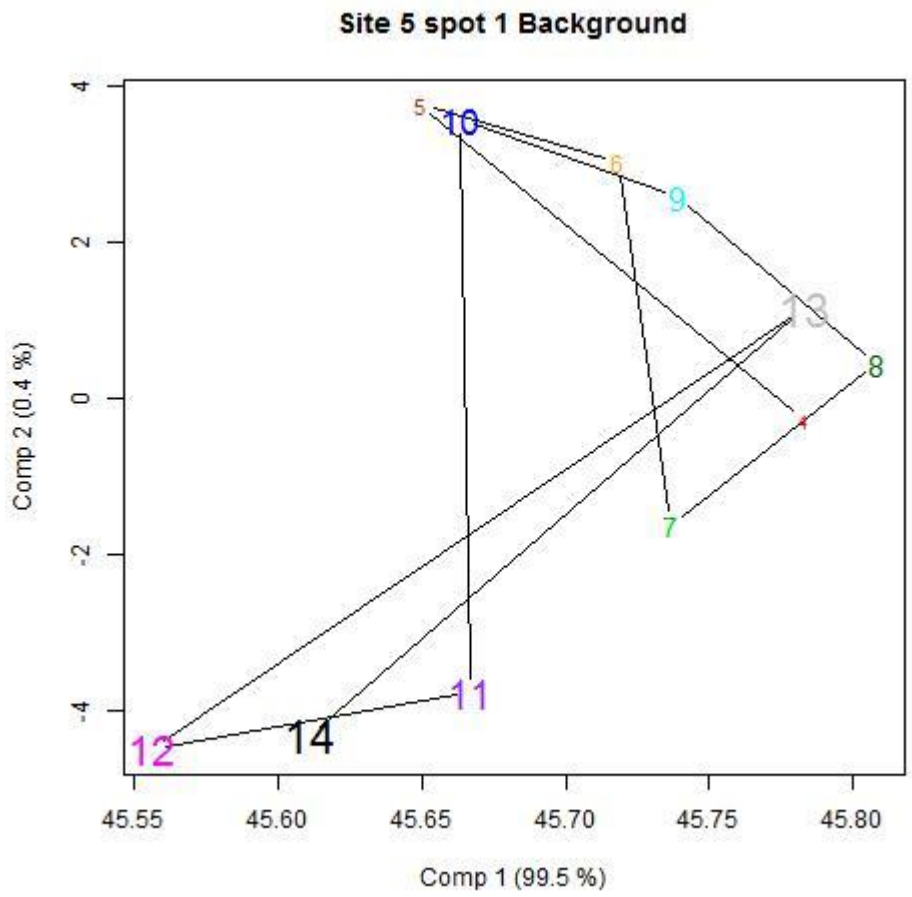
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	3.573	3.5732	0.4072	0.5412
I((4:14)^2)	1	1.930	1.9296	0.2199	0.6516
Residuals	8	70.198	8.7748		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	75.701				
2	8	70.198	2	5.5028	0.3136	0.7394



[1] Site 5 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.010913	0.0109132	1.7242	0.2256
I((4:14)^2)	1	0.000802	0.0008016	0.1267	0.7311
Residuals	8	0.050635	0.0063294		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.062350			
2	8	0.050635	2	0.011715	0.9254	0.435

[1] Site 5 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

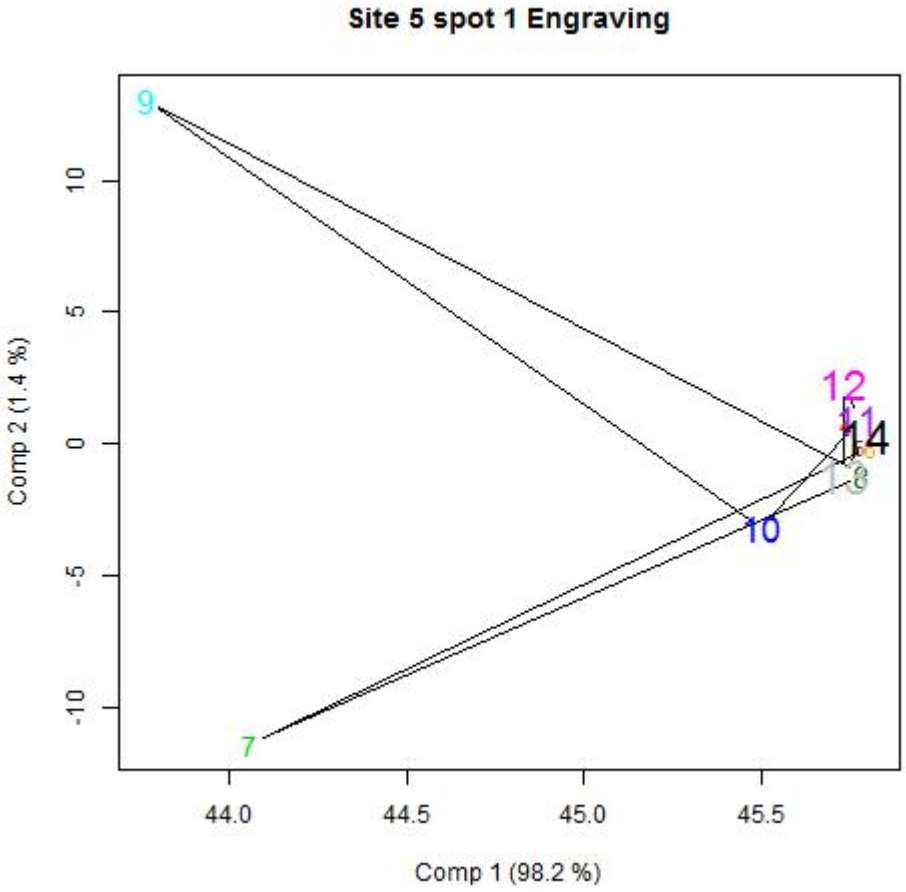
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	26.921	26.9209	3.1769	0.1125
I((4:14)^2)	1	5.331	5.3312	0.6291	0.4506
Residuals	8	67.792	8.4740		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	100.044				
2	8	67.792	2	32.252	1.903	0.2108



[1] Site 5 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0828	0.08277	0.1549	0.7042
I((4:14)^2)	1	1.2154	1.21543	2.2741	0.1700
Residuals	8	4.2757	0.53446		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	5.5739				
2	8	4.2757	2	1.2982	1.2145	0.3463

[1] Site 5 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

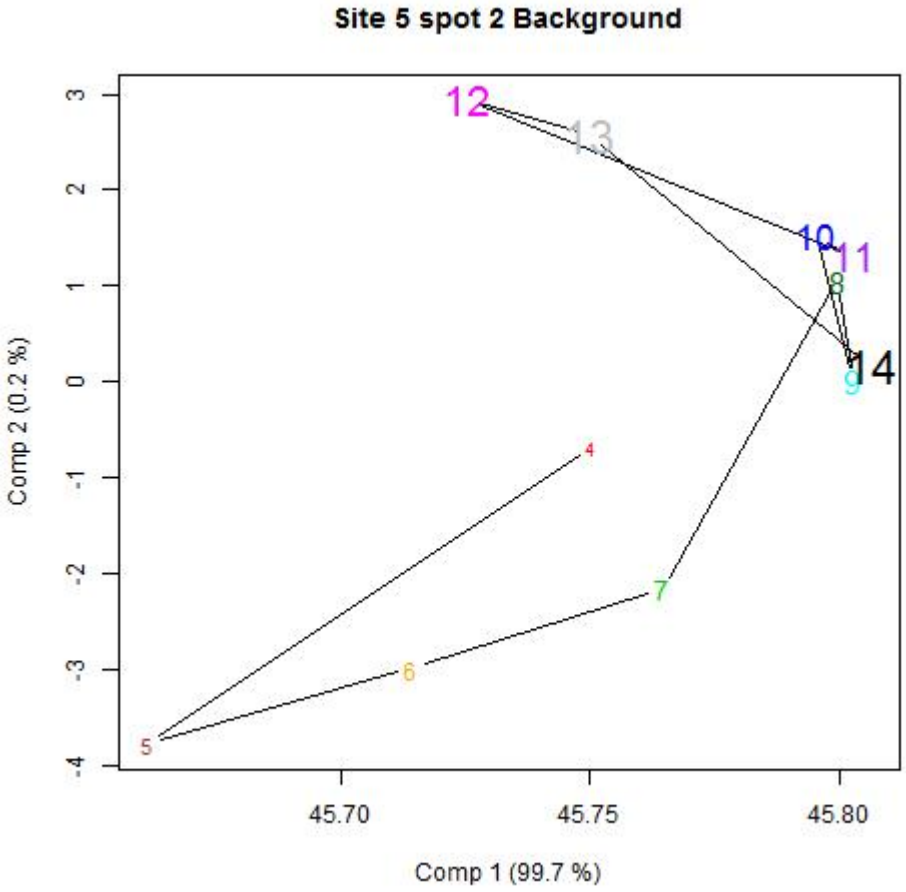
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	4.897	4.897	0.1246	0.7332
I((4:14)^2)	1	0.630	0.630	0.0160	0.9024
Residuals	8	314.424	39.303		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	319.95			
2	8	314.42	2	5.527	0.0703 0.9327



[1] Site 5 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0050149	0.0050149	2.7392	0.1365
I((4:14)^2)	1	0.0023118	0.0023118	1.2627	0.2937
Residuals	8	0.0146461	0.0018308		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.021973				
2	8	0.014646	2	0.0073267	2.001	0.1974

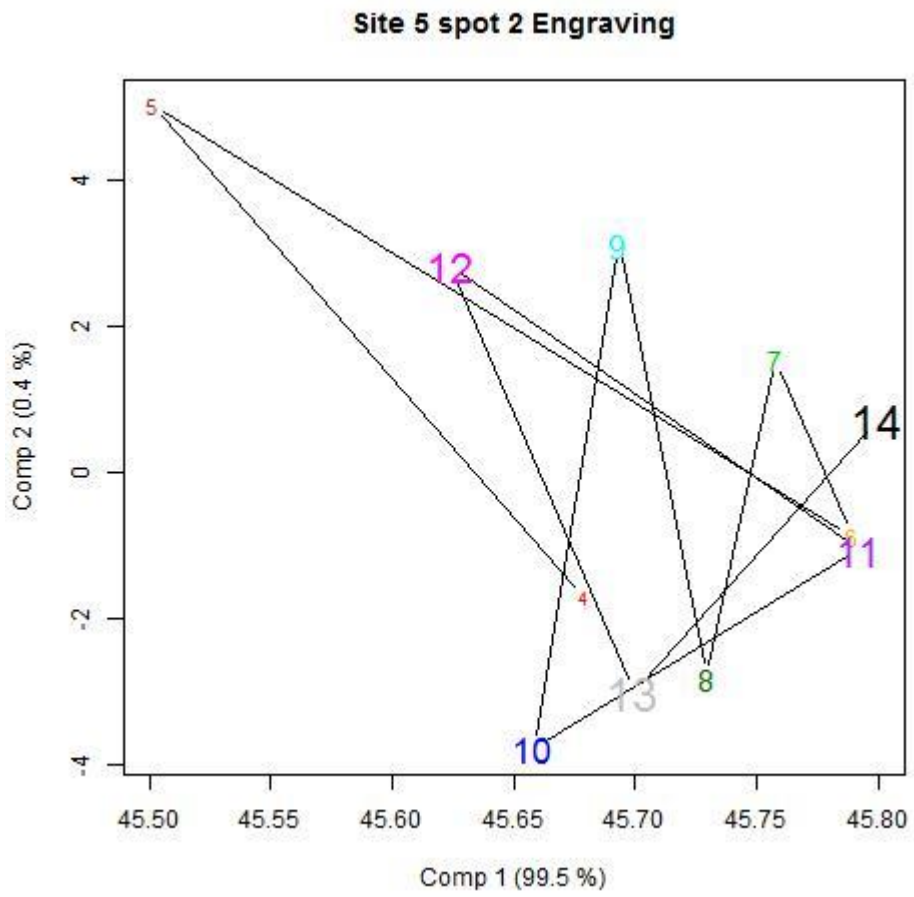
[1] Site 5 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

```
          Df Sum Sq Mean Sq F value  Pr(>F)
I(4:14)      1 27.297 27.2966 10.8422 0.01098 *
I((4:14)^2)  1  1.276  1.2760  0.5068 0.49674
Residuals    8 20.141  2.5176
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F  Pr(>F)
1     10 48.714
2      8 20.141  2    28.573 5.6745 0.02922 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 5 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.007294	0.0072942	0.8343	0.3877
I((4:14)^2)	1	0.000663	0.0006632	0.0759	0.7900
Residuals	8	0.069941	0.0087427		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.077899				
2	8	0.069941	2	0.0079574	0.4551	0.6499

[1] Site 5 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

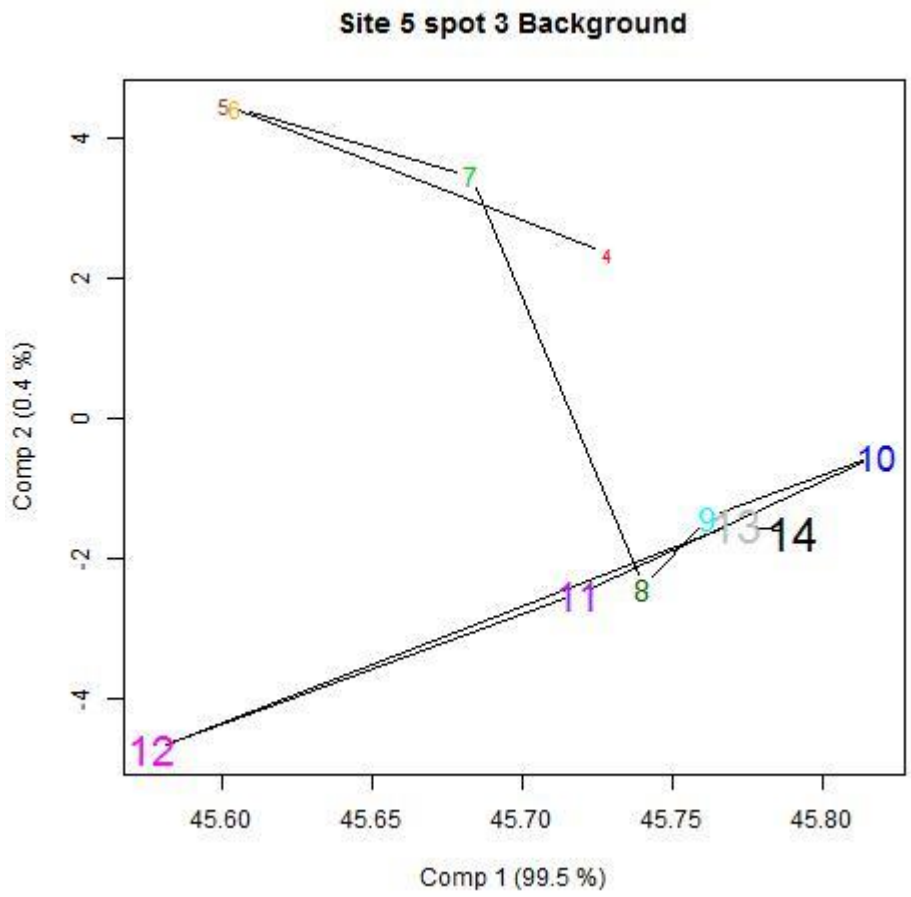
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	2.130	2.1298	0.2145	0.6556
I((4:14)^2)	1	0.484	0.4835	0.0487	0.8309
Residuals	8	79.437	9.9296		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	82.051			
2	8	79.437	2	2.6134	0.1316 0.8786



[1] Site 5 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.010167	0.0101673	1.4185	0.2678
I((4:14)^2)	1	0.000053	0.0000531	0.0074	0.9335
Residuals	8	0.057340	0.0071674		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.06756			
2	8	0.05734	2	0.01022	0.713 0.5189

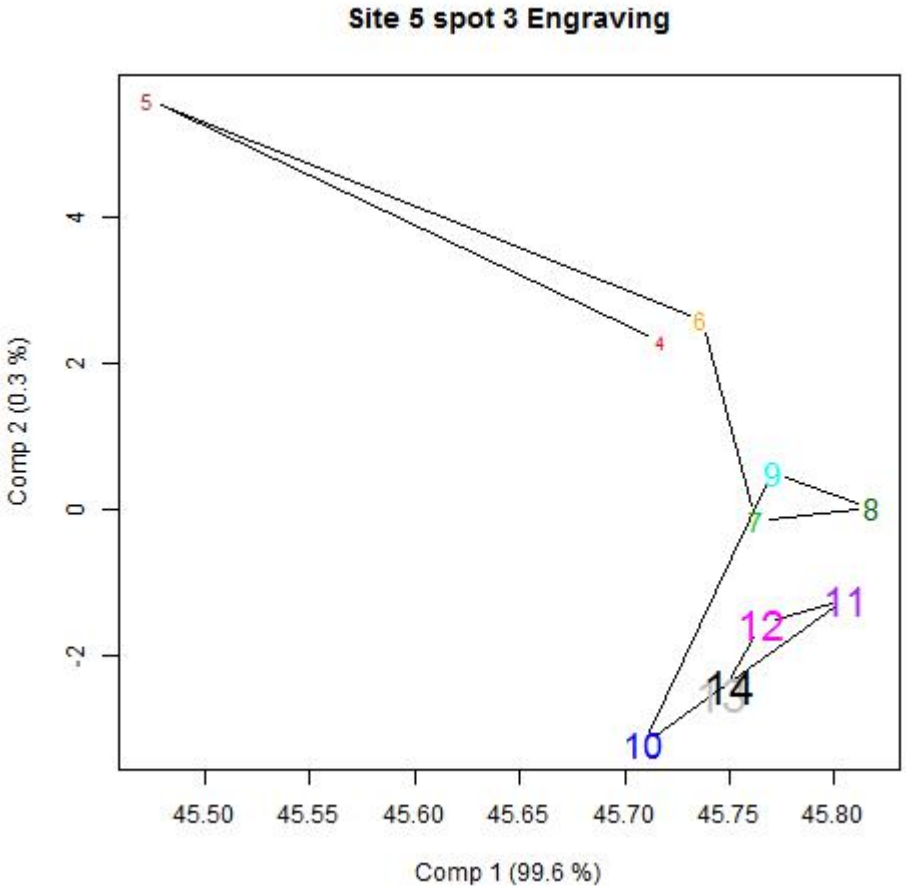
[1] Site 5 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

```
          Df Sum Sq Mean Sq F value   Pr(>F)
I(4:14)      1 60.105  60.105  14.198 0.005481 **
I((4:14)^2)  1  4.737   4.737   1.119 0.321025
Residuals    8 33.866   4.233
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F  Pr(>F)
1     10 98.709
2      8 33.866  2    64.842 7.6586 0.01386 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 5 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.015899	0.0158991	2.1774	0.1783
I((4:14)^2)	1	0.010718	0.0107177	1.4678	0.2603
Residuals	8	0.058415	0.0073019		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.085032			
2	8	0.058415	2	0.026617	1.8226	0.2227

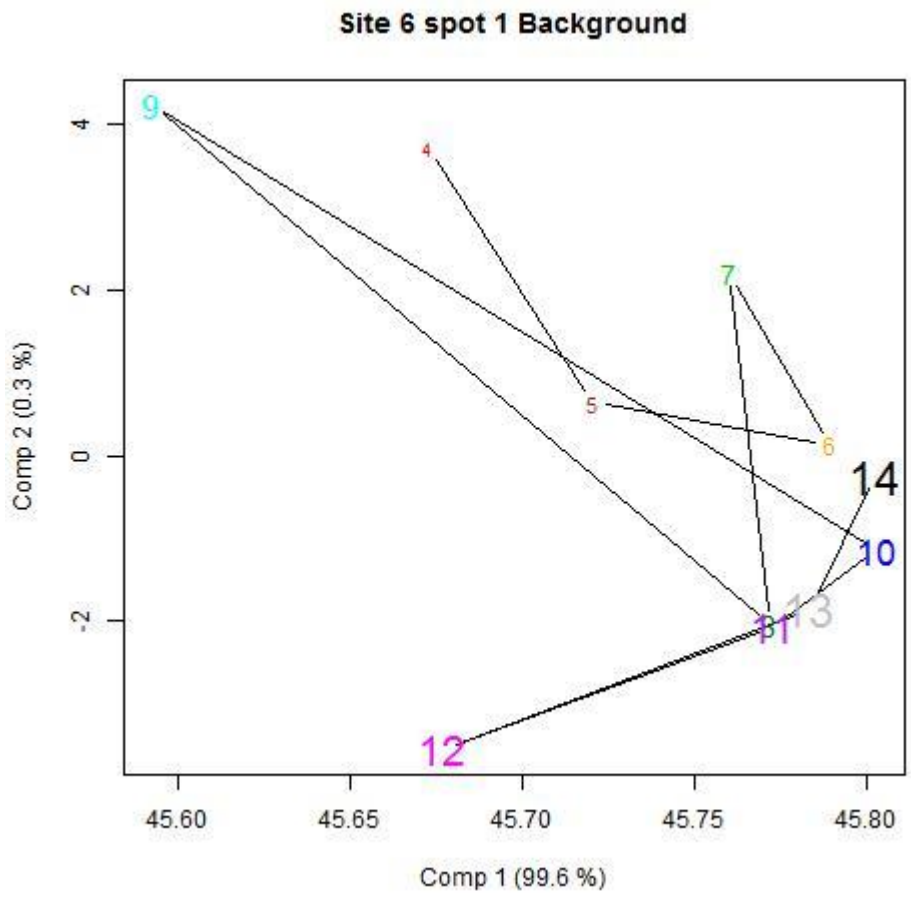
[1] Site 5 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
          Df Sum Sq Mean Sq F value    Pr(>F)
I(4:14)      1 49.528  49.528 22.2524 0.001508 **
I((4:14)^2)  1  2.662   2.662  1.1959 0.305975
Residuals    8 17.806   2.226
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F   Pr(>F)
1     10 69.995
2      8 17.806  2     52.19 11.724 0.004188 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 6 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.003511	0.0035111	0.6743	0.4353
I((4:14)^2)	1	0.000183	0.0001831	0.0352	0.8559
Residuals	8	0.041658	0.0052072		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.045352				
2	8	0.041658	2	0.0036943	0.3547	0.7119

[1] Site 6 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	21.394	21.3940	4.2645	0.07279 .
I((4:14)^2)	1	1.302	1.3015	0.2594	0.62426
Residuals	8	40.134	5.0168		

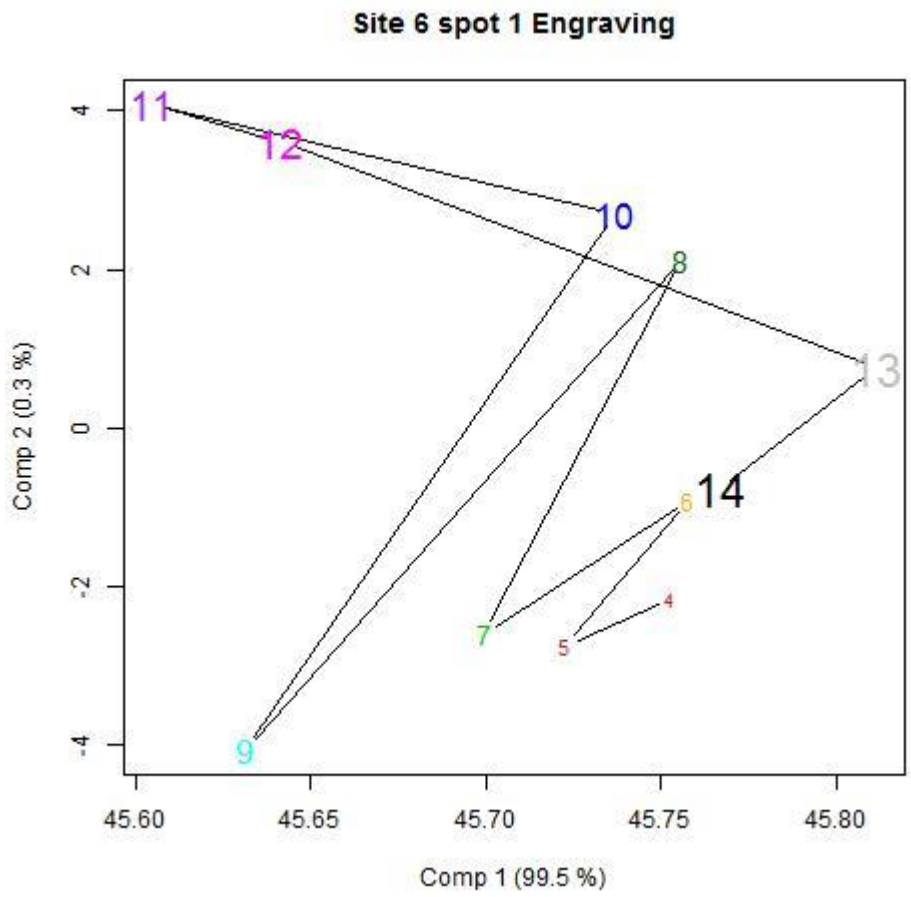
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	62.830				
2	8	40.134	2	22.695	2.262	0.1665



[1] Site 6 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0001598	0.0001598	0.0407	0.8451
I((4:14)^2)	1	0.0106700	0.0106700	2.7185	0.1378
Residuals	8	0.0313996	0.0039250		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.042229			
2	8	0.031400	2	0.01083	1.3796	0.3057

[1] Site 6 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

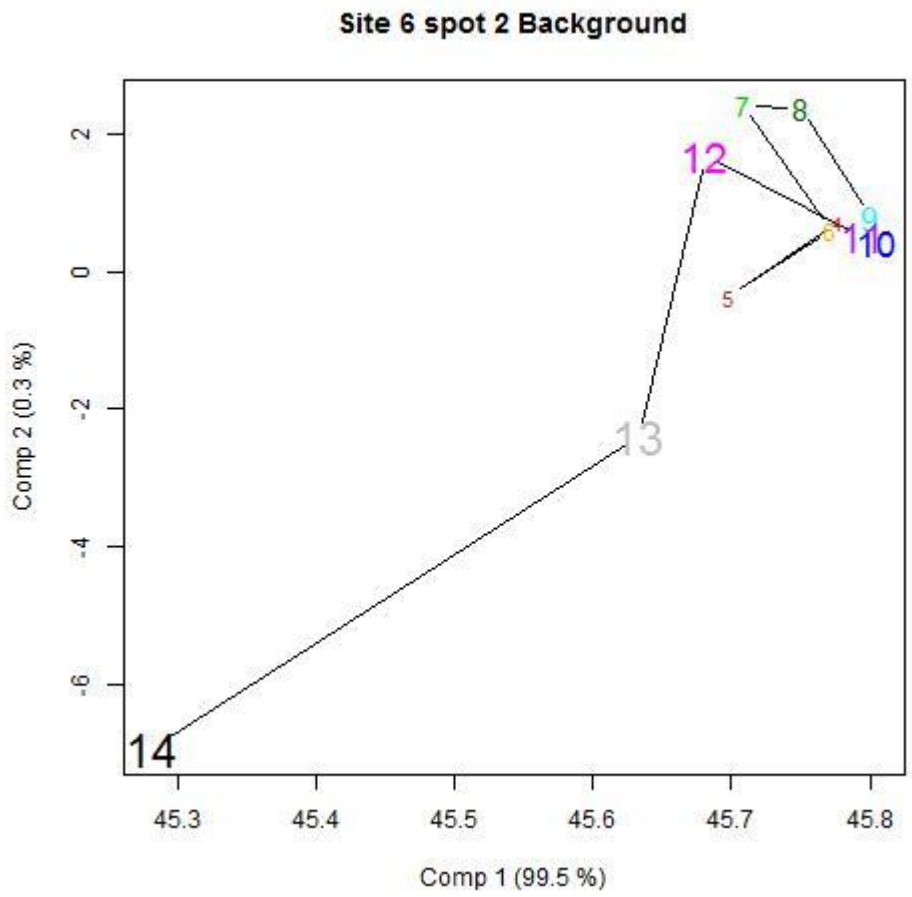
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	21.281	21.2810	3.2974	0.1069
I((4:14)^2)	1	5.737	5.7372	0.8889	0.3734
Residuals	8	51.631	6.4539		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	78.649				
2	8	51.631	2	27.018	2.0932	0.1857



[1] Site 6 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:14)	1	0.070385	0.070385	8.3849	0.02002	*
I((4:14)^2)	1	0.085967	0.085967	10.2412	0.01261	*
Residuals	8	0.067154	0.008394			

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(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.223506				
2	8	0.067154	2	0.15635	9.3131	0.008149 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

[1] Site 6 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:14)	1	21.836	21.8357	9.8622	0.013797	*
I((4:14)^2)	1	31.172	31.1725	14.0792	0.005606	**
Residuals	8	17.713	2.2141			

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

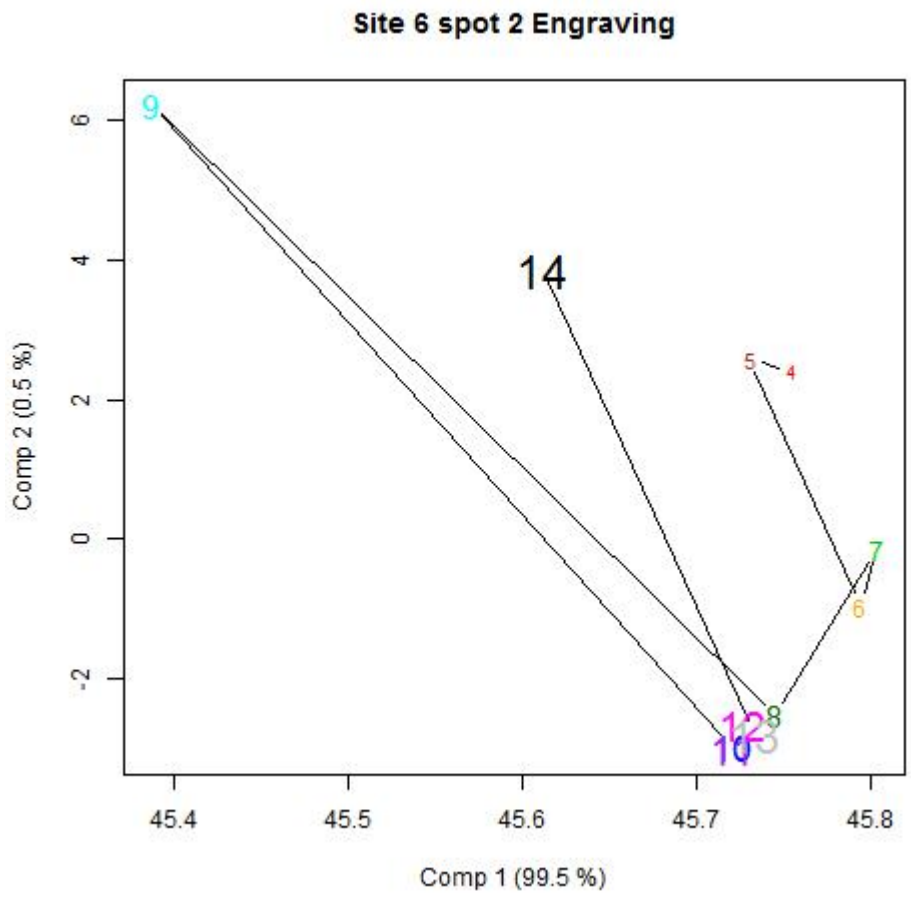
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)	
1	10	70.721				
2	8	17.713	2	53.008	11.971	0.003935 **

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



[1] Site 6 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.010991	0.0109910	0.7323	0.4170
I((4:14)^2)	1	0.002845	0.0028448	0.1896	0.6748
Residuals	8	0.120064	0.0150079		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.13390				
2	8	0.12006	2	0.013836	0.461	0.6464

[1] Site 6 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

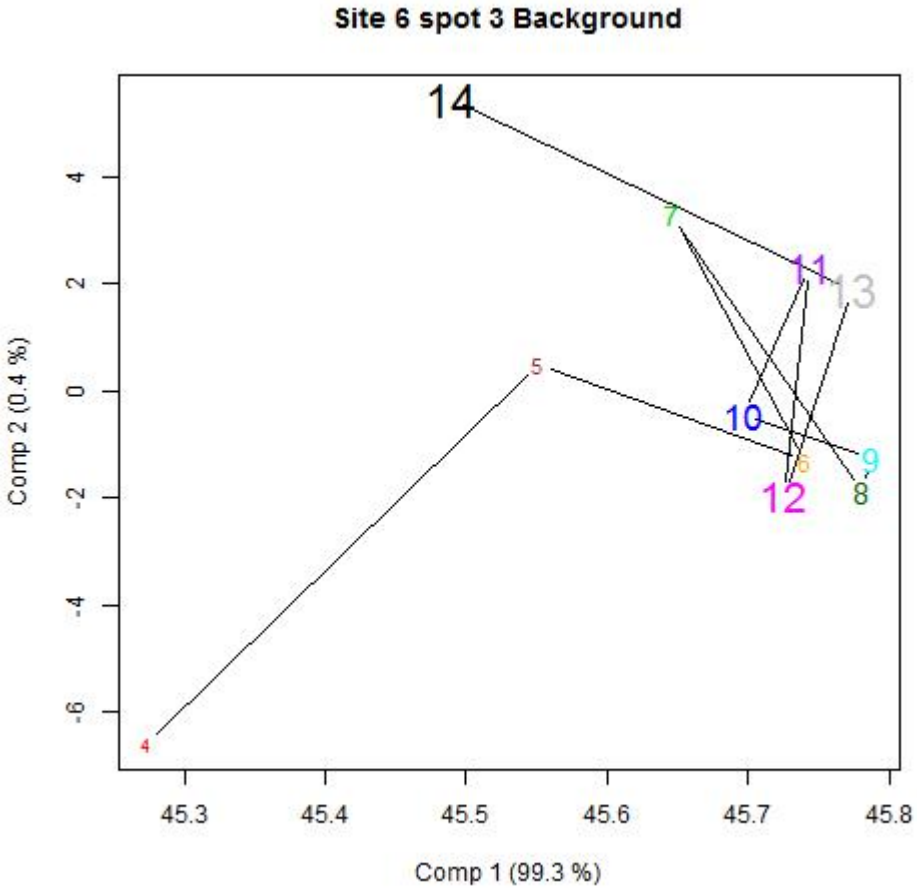
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	5.904	5.9036	0.5361	0.4850
I((4:14)^2)	1	12.260	12.2596	1.1132	0.3222
Residuals	8	88.102	11.0128		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	106.266				
2	8	88.102	2	18.163	0.8246	0.4725



[1] Site 6 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
I(4:14)	1	0.037532	0.037532	5.0797	0.05424	.
I((4:14)^2)	1	0.156207	0.156207	21.1419	0.00176	**
Residuals	8	0.059108	0.007389			

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(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.252847			
2	8	0.059108	2	0.19374	13.111	0.002986 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

[1] Site 6 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	36.336	36.336	4.3206	0.07127 .
I((4:14)^2)	1	0.000	0.000	0.0000	0.99934
Residuals	8	67.280	8.410		

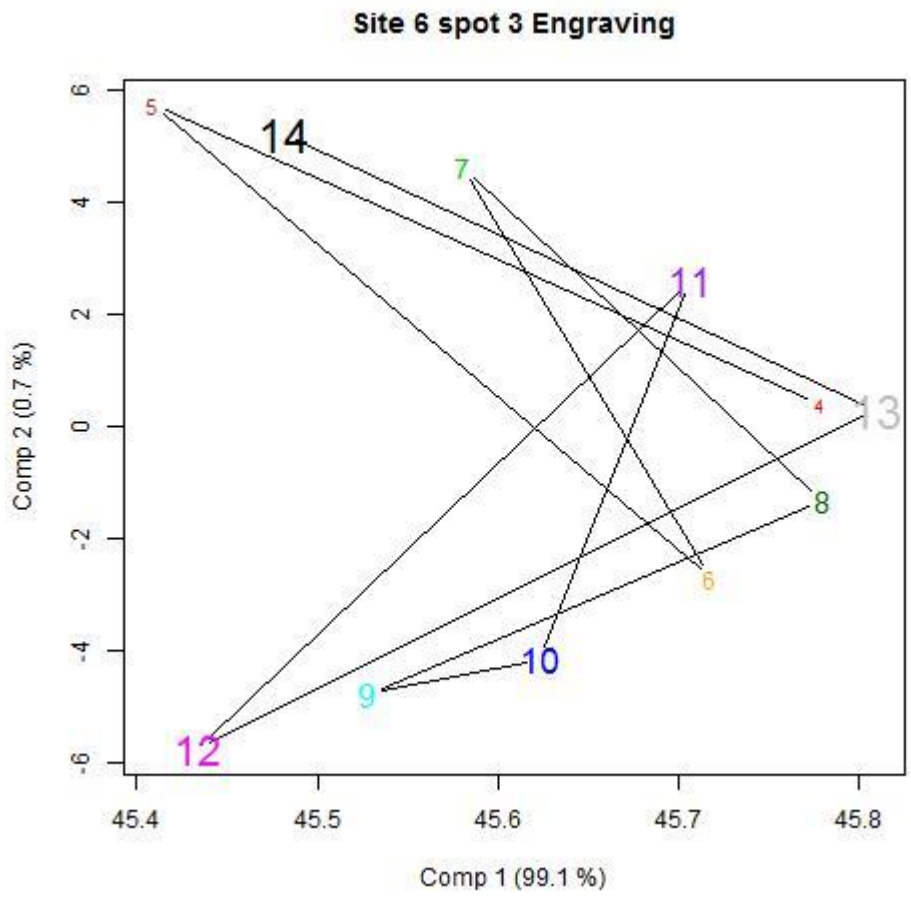
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	103.62				
2	8	67.28	2	36.336	2.1603	0.1778



[1] Site 6 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.003698	0.0036979	0.1421	0.7160
I((4:14)^2)	1	0.000398	0.0003982	0.0153	0.9046
Residuals	8	0.208188	0.0260235		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.21228			
2	8	0.20819	2	0.0040961	0.0787	0.925

[1] Site 6 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

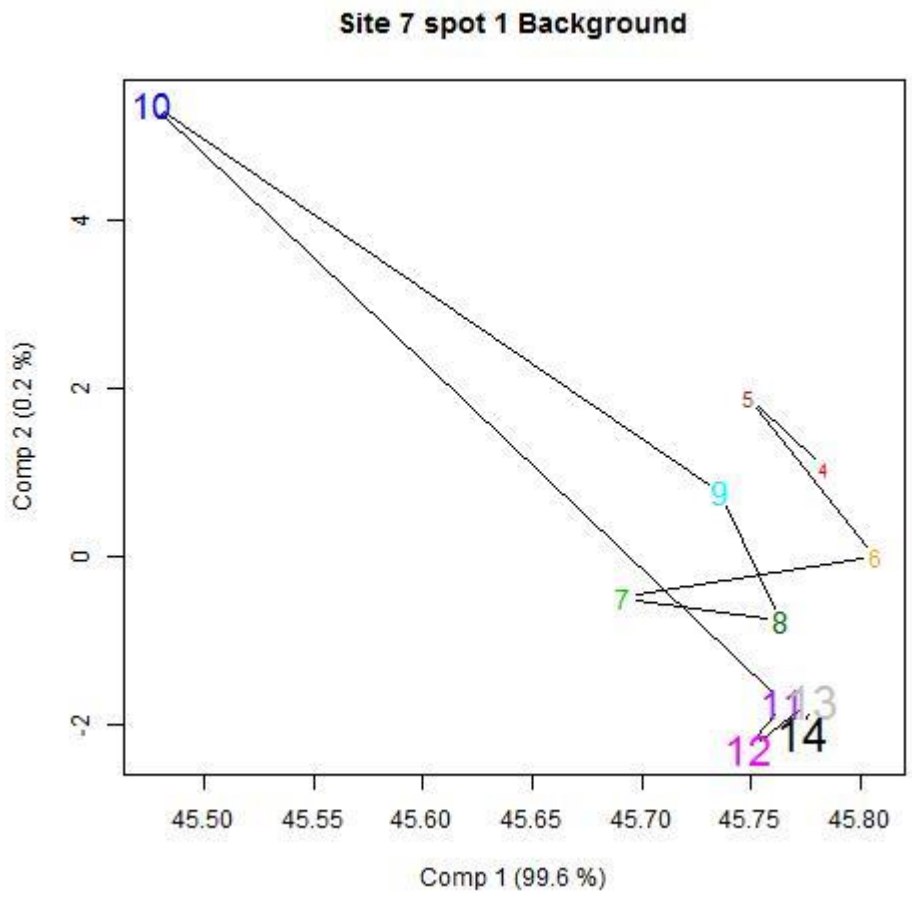
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	1.702	1.702	0.1047	0.7546
I((4:14)^2)	1	38.737	38.737	2.3816	0.1613
Residuals	8	130.124	16.266		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	170.56			
2	8	130.12	2	40.44	1.2431 0.3388



[1] Site 7 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000569	0.0005688	0.0700	0.7981
I((4:14)^2)	1	0.016047	0.0160474	1.9739	0.1977
Residuals	8	0.065039	0.0081299		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.081655				
2	8	0.065039	2	0.016616	1.0219	0.4025

[1] Site 7 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

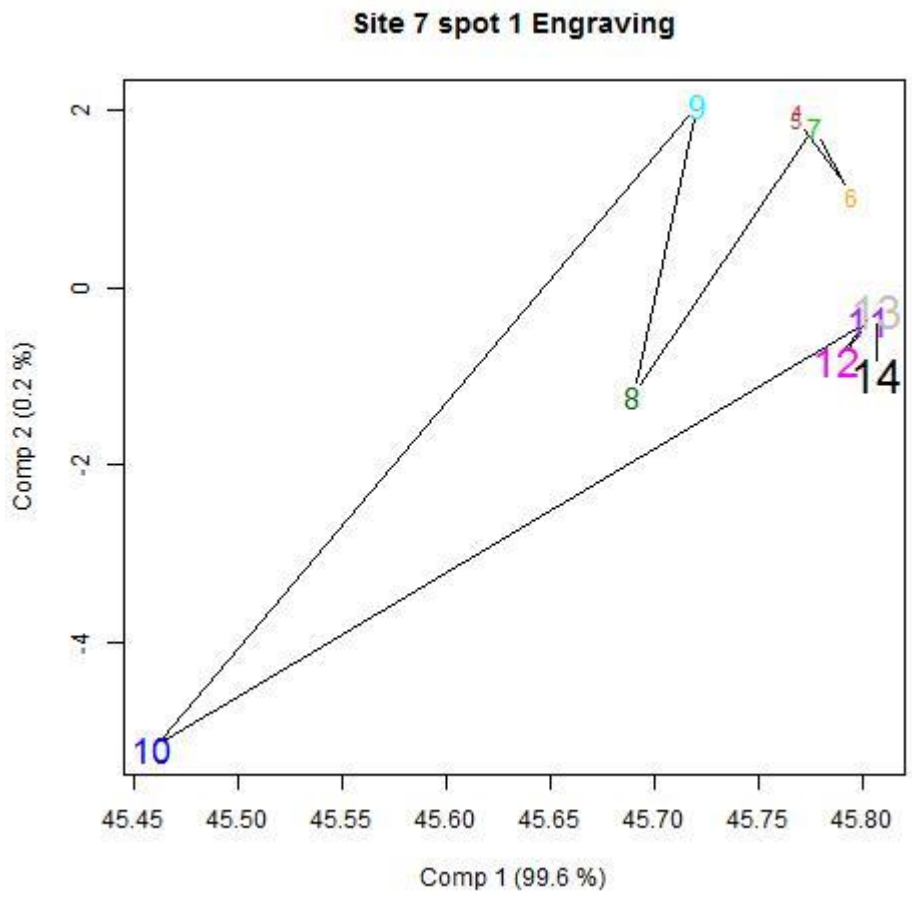
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	10.107	10.1066	2.1381	0.1818
I((4:14)^2)	1	2.682	2.6824	0.5675	0.4728
Residuals	8	37.815	4.7268		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	50.604				
2	8	37.815	2	12.789	1.3528	0.3118



[1] Site 7 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000170	0.0001703	0.0172	0.8988
I((4:14)^2)	1	0.023320	0.0233196	2.3622	0.1629
Residuals	8	0.078976	0.0098720		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.102466				
2	8	0.078976	2	0.02349	1.1897	0.3529

[1] Site 7 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

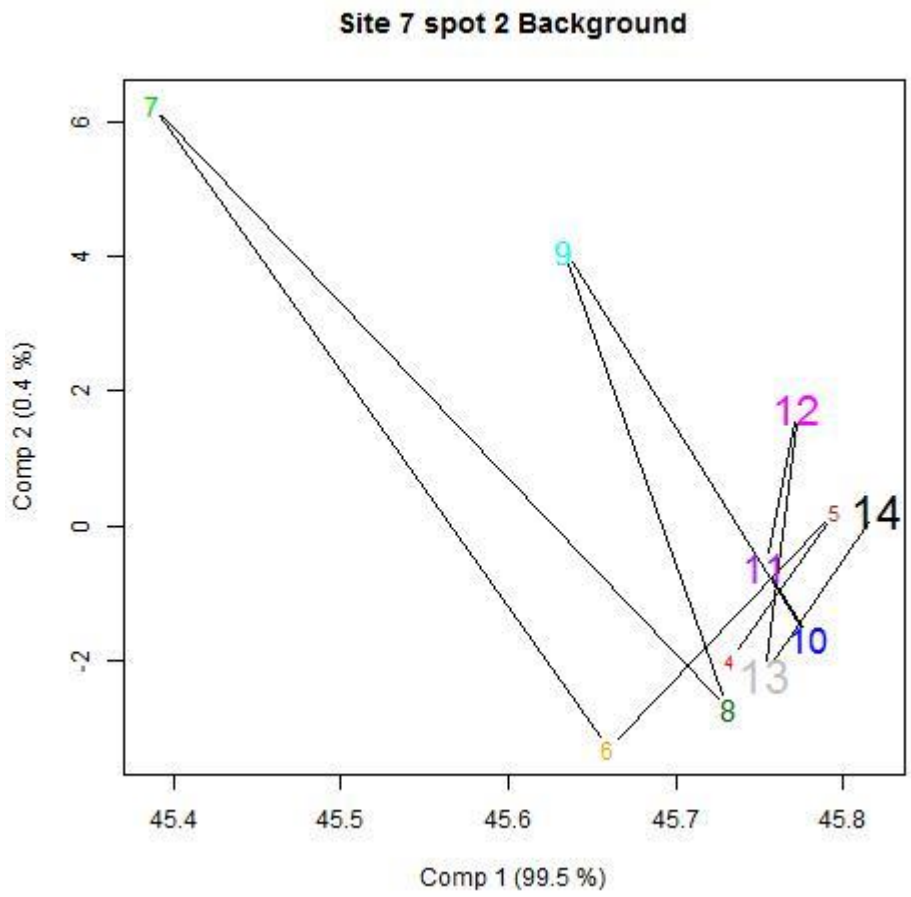
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	12.6888	12.6888	3.3379	0.1051
I((4:14)^2)	1	3.3447	3.3447	0.8799	0.3757
Residuals	8	30.4111	3.8014		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	46.445				
2	8	30.411	2	16.034	2.1089	0.1838



[1] Site 7 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.017390	0.017390	1.3184	0.2840
I((4:14)^2)	1	0.022209	0.022209	1.6838	0.2306
Residuals	8	0.105521	0.013190		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.14512			
2	8	0.10552	2	0.039599	1.5011	0.2795

[1] Site 7 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

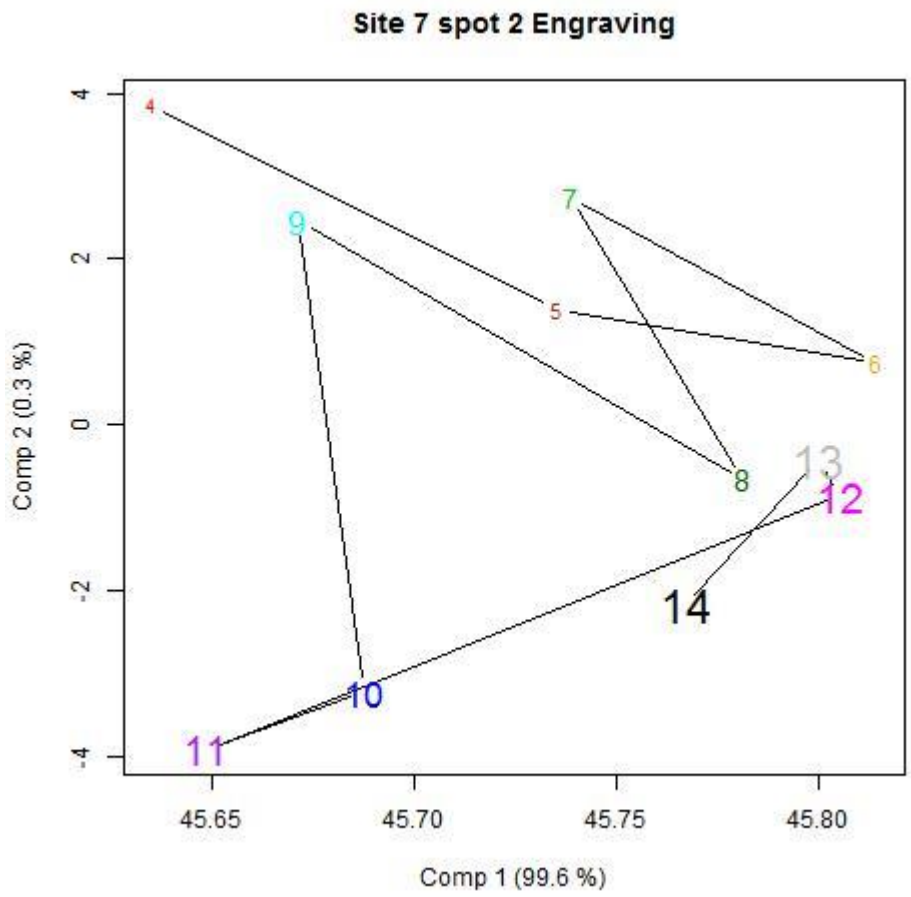
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.149	0.1490	0.0144	0.9074
I((4:14)^2)	1	6.042	6.0423	0.5838	0.4668
Residuals	8	82.803	10.3504		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	88.995				
2	8	82.803	2	6.1913	0.2991	0.7494



[1] Site 7 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.003475	0.0034749	0.7212	0.4204
I((4:14)^2)	1	0.000156	0.0001561	0.0324	0.8616
Residuals	8	0.038543	0.0048179		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.042174				
2	8	0.038543	2	0.0036309	0.3768	0.6976

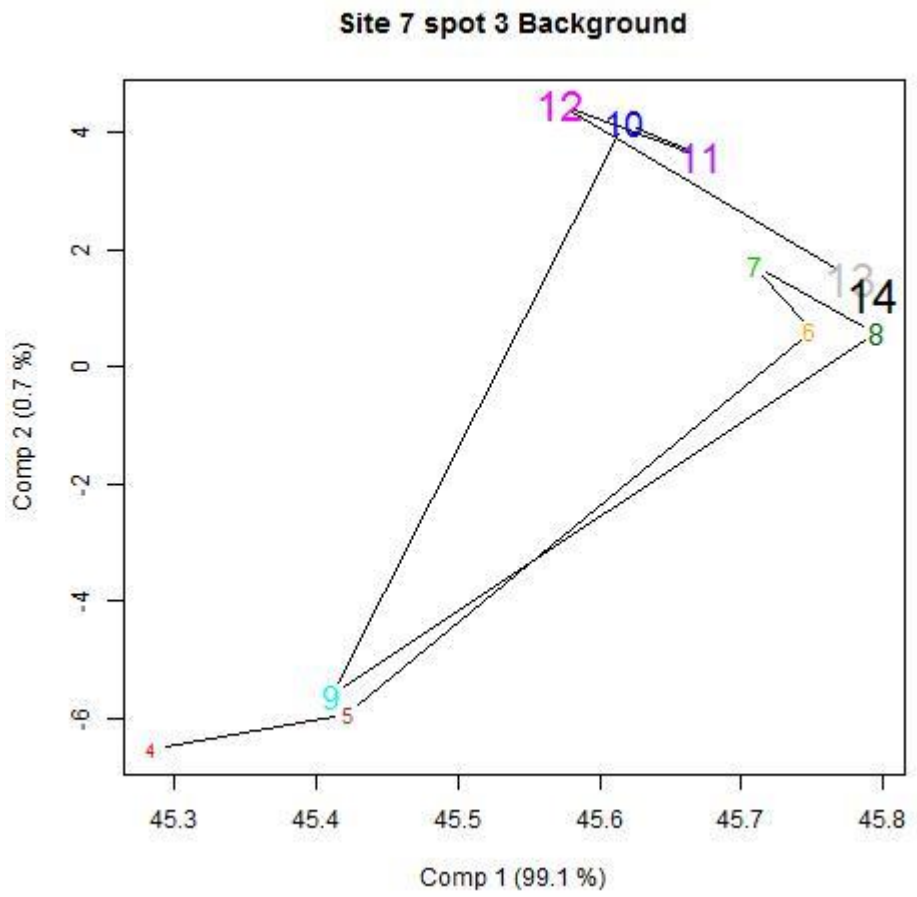
[1] Site 7 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
          Df  Sum Sq Mean Sq F value  Pr(>F)
I(4:14)      1 30.6232 30.6232  8.4033 0.01993 *
I((4:14)^2)  1  2.7481  2.7481  0.7541 0.41047
Residuals    8 29.1536  3.6442
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq      F  Pr(>F)
1     10 62.525
2      8 29.154  2    33.371 4.5787 0.04727 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 7 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.092014	0.092014	3.5505	0.09627 .
I((4:14)^2)	1	0.011119	0.011119	0.4291	0.53083
Residuals	8	0.207326	0.025916		

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(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.31046				
2	8	0.20733	2	0.10313	1.9898	0.1989

[1] Site 7 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

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

I(4:14) 1 69.401 69.401 7.1423 0.02825 *

I((4:14)^2) 1 19.542 19.542 2.0112 0.19390

Residuals 8 77.735 9.717

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

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

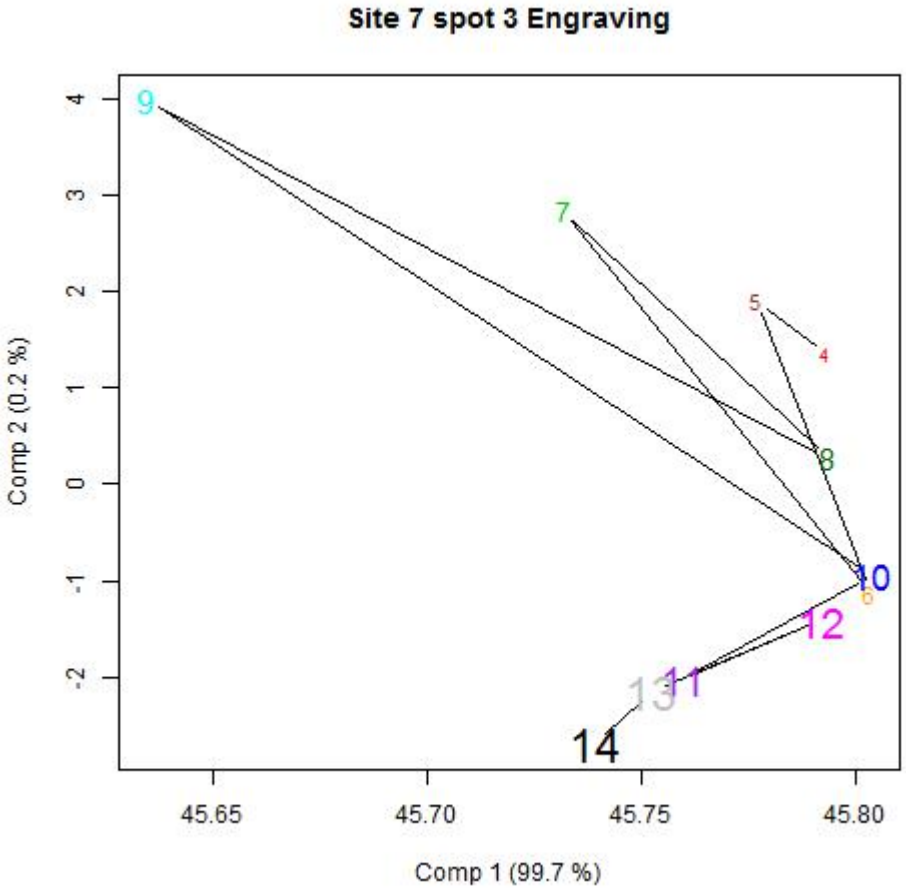
Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

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

1 10 166.678

2 8 77.735 2 88.943 4.5767 0.04731 *

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



[1] Site 7 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.0010179	0.00101788	0.3663	0.5618
I((4:14)^2)	1	0.0009407	0.00094072	0.3385	0.5767
Residuals	8	0.0222294	0.00277867		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.024188				
2	8	0.022229	2	0.0019586	0.3524	0.7134

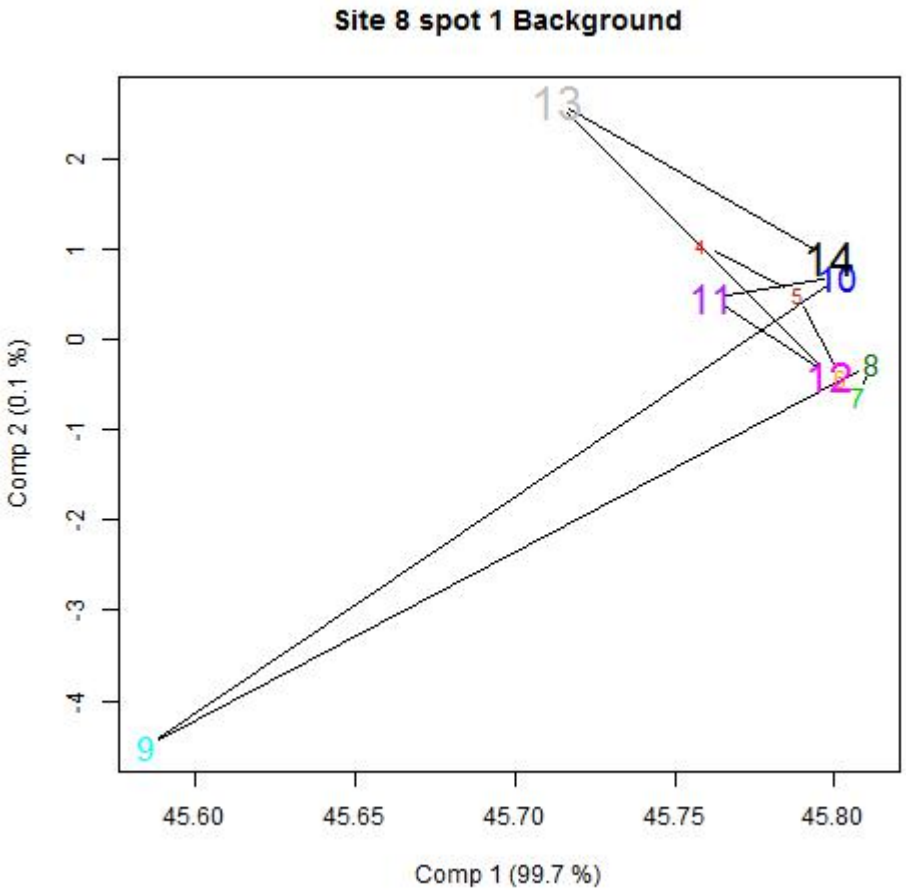
[1] Site 7 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

```
          Df  Sum Sq Mean Sq F value  Pr(>F)
I(4:14)      1 21.2316 21.2316  6.9154 0.03019 *
I((4:14)^2)  1  3.8763  3.8763  1.2626 0.29375
Residuals    8 24.5615  3.0702
---
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(4:14) + I((4:14)^2)
  Res.Df    RSS Df Sum of Sq     F  Pr(>F)
1     10 49.669
2      8 24.561  2    25.108 4.089 0.05979 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```



[1] Site 8 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.000407	0.0004073	0.0756	0.7903
I((4:14)^2)	1	0.001148	0.0011479	0.2132	0.6566
Residuals	8	0.043074	0.0053842		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.044629				
2	8	0.043074	2	0.0015552	0.1444	0.8677

[1] Site 8 spot 1 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	1.0939	1.0939	0.4370	0.52715
I((4:14)^2)	1	9.6745	9.6745	3.8648	0.08488 .
Residuals	8	20.0261	2.5033		

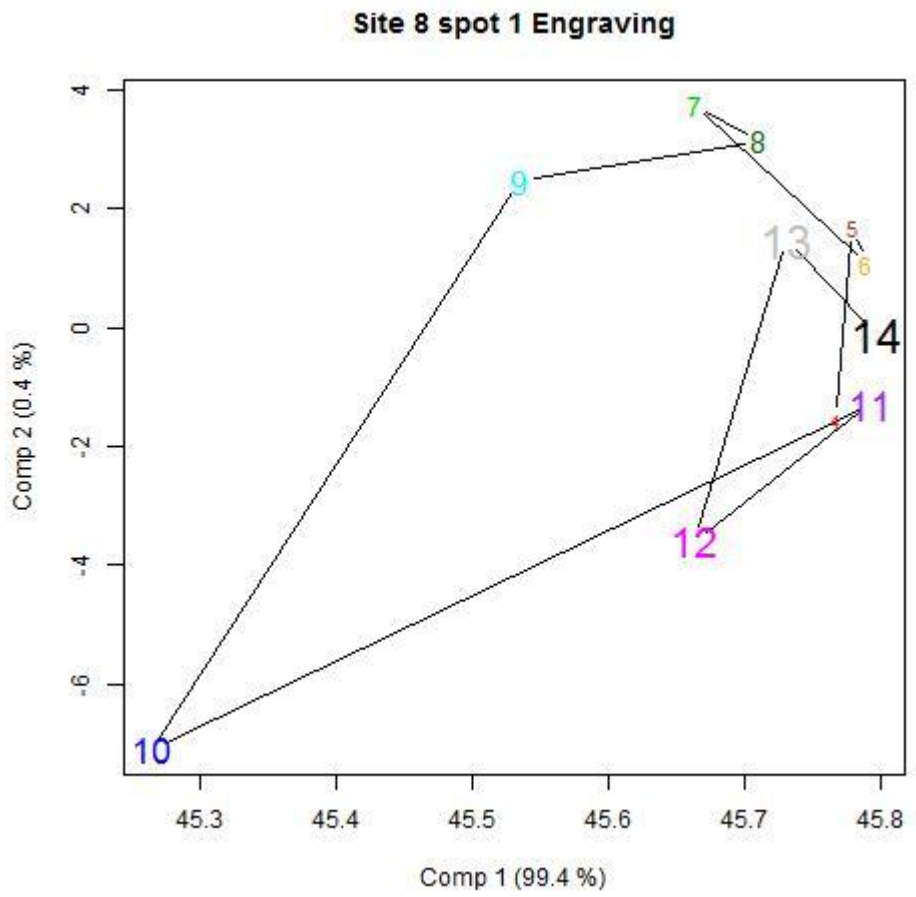
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	30.794			
2	8	20.026	2	10.768	2.1509 0.1789



[1] Site 8 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.003404	0.003404	0.1592	0.70034
I((4:14)^2)	1	0.077970	0.077970	3.6465	0.09259 .
Residuals	8	0.171058	0.021382		

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(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.25243			

2 8 0.17106 2 0.081373 1.9028 0.2109

[1] Site 8 spot 1 Engraving

Analysis of Variance Table

Response: coefs[i,]

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

I(4:14) 1 7.001 7.0009 0.5823 0.4673

I((4:14)^2) 1 0.065 0.0655 0.0054 0.9430

Residuals 8 96.188 12.0235

Analysis of Variance Table

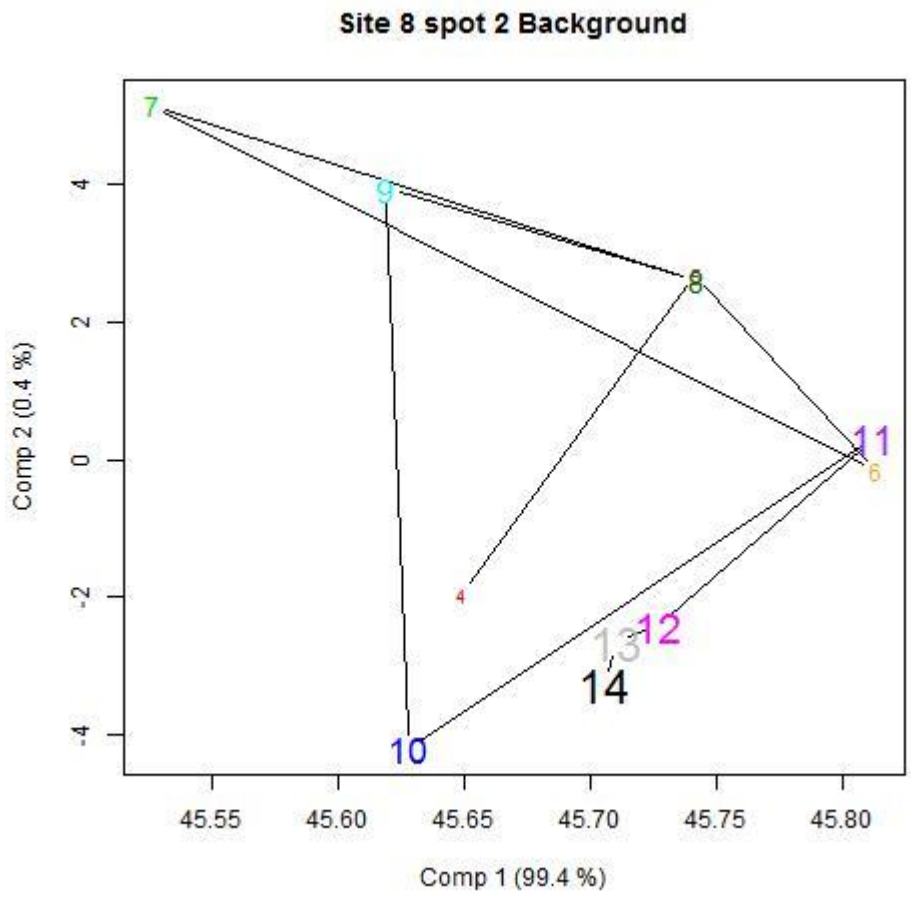
Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

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

1 10 103.254

2 8 96.188 2 7.0664 0.2939 0.7531



[1] Site 8 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.001122	0.0011219	0.1246	0.7332
I((4:14)^2)	1	0.001027	0.0010273	0.1141	0.7442
Residuals	8	0.072014	0.0090017		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.074163				
2	8	0.072014	2	0.0021492	0.1194	0.889

[1] Site 8 spot 2 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	23.773	23.7728	3.3586	0.1042
I((4:14)^2)	1	20.657	20.6565	2.9183	0.1260
Residuals	8	56.625	7.0782		

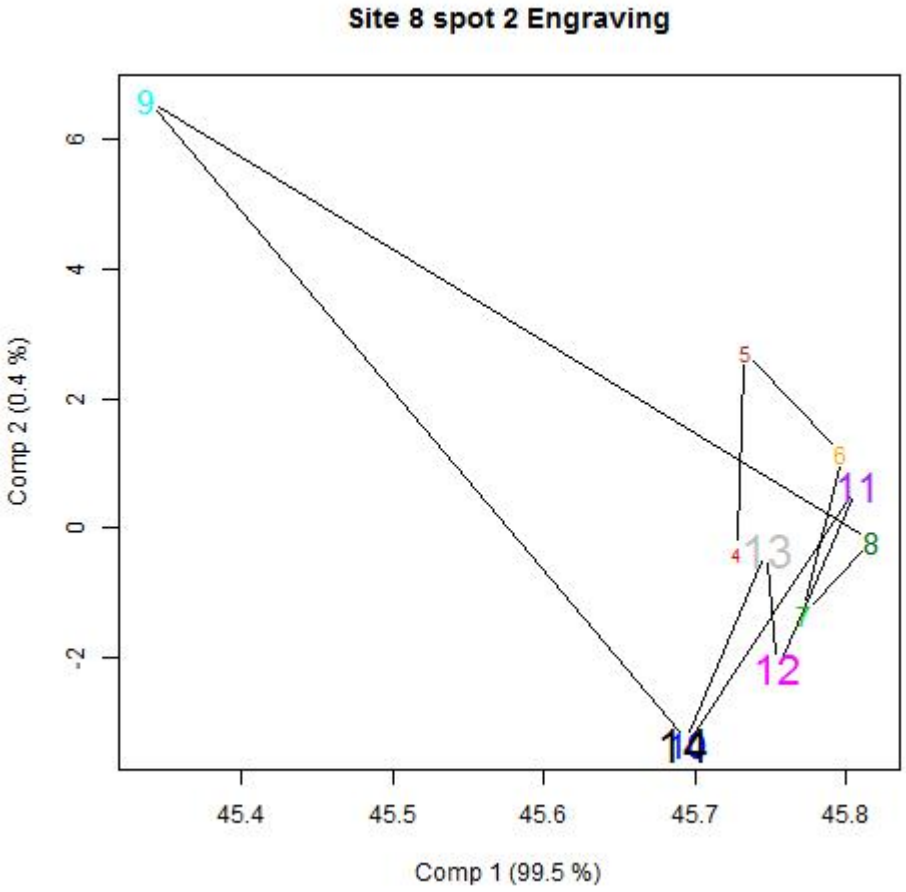
Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	101.055			
2	8	56.625	2	44.429	3.1385 0.09859 .

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(4:14)	1	0.000791	0.0007906	0.0375	0.8513
I((4:14)^2)	1	0.005591	0.0055907	0.2651	0.6206
Residuals	8	0.168732	0.0210915		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.17511				
2	8	0.16873	2	0.0063813	0.1513	0.862

[1] Site 8 spot 2 Engraving

Analysis of Variance Table

Response: coefs[i,]

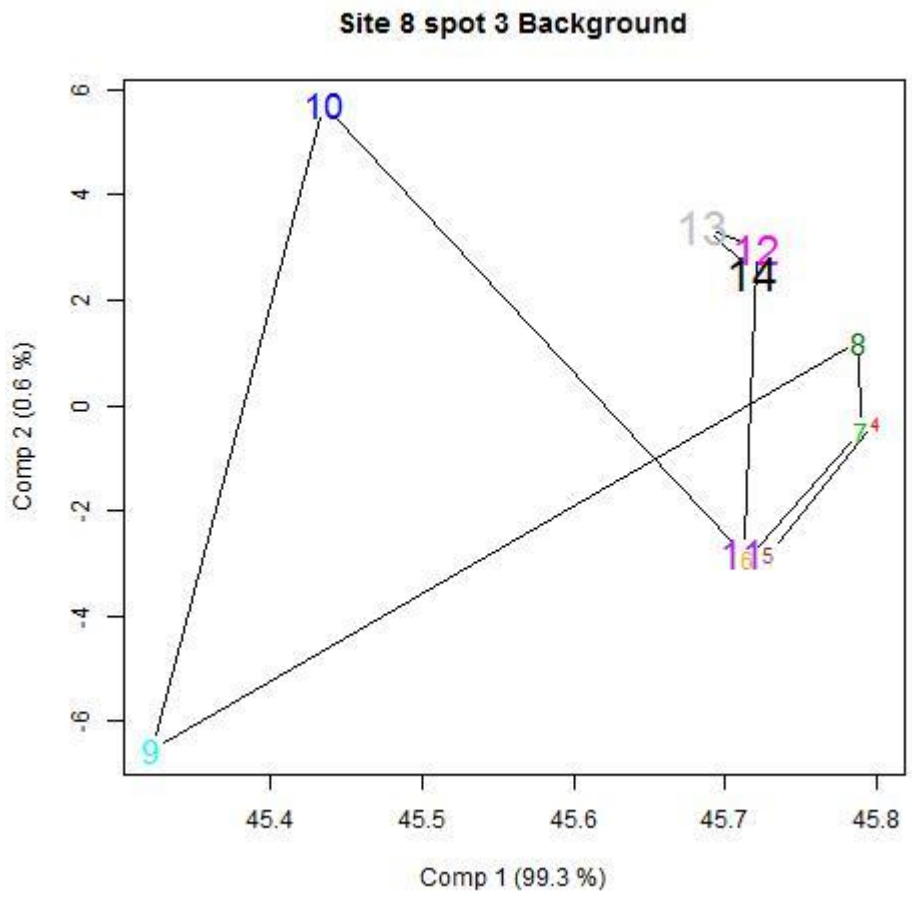
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	11.775	11.7750	1.4694	0.2600
I((4:14)^2)	1	5.892	5.8923	0.7353	0.4161
Residuals	8	64.109	8.0137		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	81.777				
2	8	64.109	2	17.667	1.1023	0.3777



[1] Site 8 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.010477	0.010477	0.4859	0.5055
I((4:14)^2)	1	0.050458	0.050458	2.3401	0.1646
Residuals	8	0.172503	0.021563		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.23344				
2	8	0.17250	2	0.060935	1.413	0.2982

[1] Site 8 spot 3 Background

Analysis of Variance Table

Response: coefs[i,]

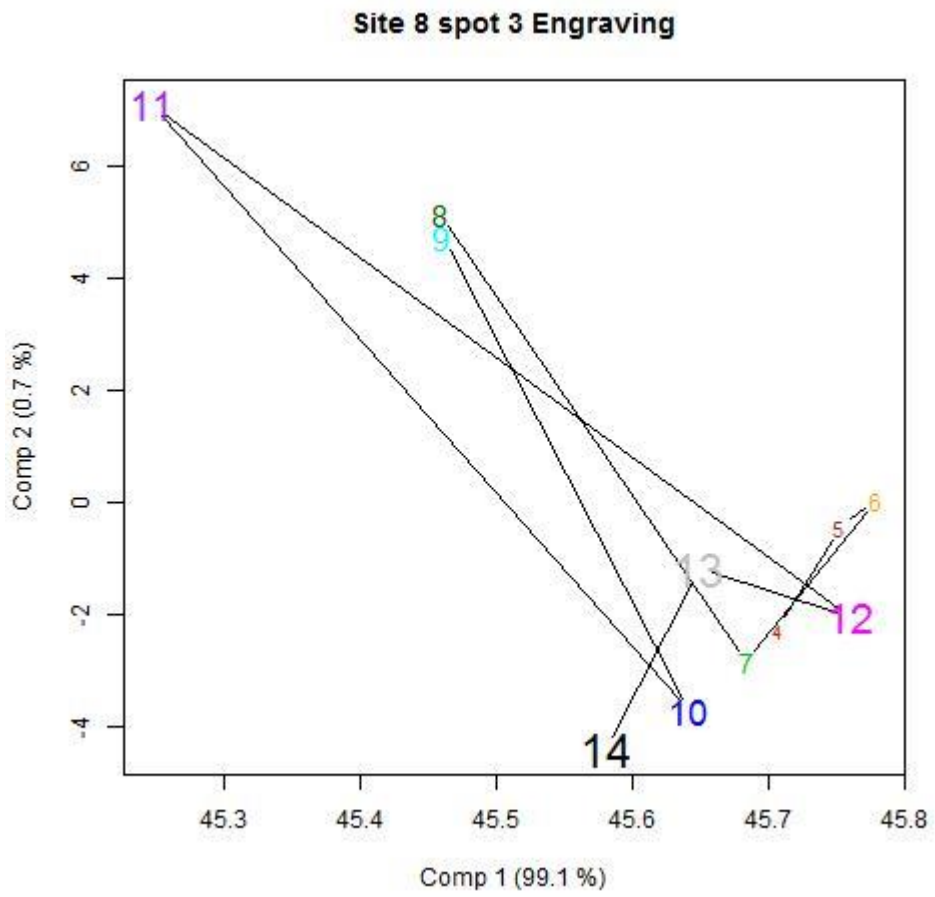
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	29.068	29.0684	2.4533	0.1559
I((4:14)^2)	1	4.145	4.1446	0.3498	0.5706
Residuals	8	94.790	11.8487		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	128.00				
2	8	94.79	2	33.213	1.4015	0.3007



[1] Site 8 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.029222	0.029222	1.2049	0.3043
I((4:14)^2)	1	0.042900	0.042900	1.7688	0.2202
Residuals	8	0.194028	0.024254		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	0.26615			
2	8	0.19403	2	0.072123	1.4868 0.2825

[1] Site 8 spot 3 Engraving

Analysis of Variance Table

Response: coefs[i,]

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
I(4:14)	1	0.692	0.692	0.0518	0.8256
I((4:14)^2)	1	43.618	43.618	3.2655	0.1084
Residuals	8	106.857	13.357		

Analysis of Variance Table

Model 1: coefs[i,] ~ 1

Model 2: coefs[i,] ~ I(4:14) + I((4:14)^2)

Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	10	151.17			
2	8	106.86	2	44.31	1.6587 0.2497

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FOR FURTHER INFORMATION

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