

IN CONFIDENCE

DEPARTMENT OF CONSERVATION AND SCIENTIFIC RESEARCH

Examination of patches on a map of the east coast of North America by John White  
("La Virginea Pars";1906,0509.1.3)

CSR ANALYTICAL REQUEST NO. AR2012-21

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**Abstract:** Two patches applied to a map of the east coast of North America drawn by the Elizabethan gentleman and artist John White were investigated. Both patches were imaged using visible reflected, visible transmitted, infrared-reflected, ultraviolet-reflected and ultraviolet-induced luminescence imaging and by infrared reflectography. Image processing was then applied to clarify the resulting images. The imaging work revealed that one patch concealed slight changes to the coastline. The other hid a large red and blue symbol and had a very faint version of a similar symbol drawn on its surface. Enhanced images of both symbols were produced.

The pigments used were also investigated by optical microscopy, X-ray fluorescence and Raman spectroscopy. The black sketch lines were confirmed to be of graphite and the blue lines to be indigo. The coats of arms are coloured with metallic silver, smalt, orpiment and a mixture of red lead and vermilion. Hematite and a probable red lake pigment were also found.

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Analysis requested by K Sloan (P&D)

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BM object registration and PRN number(s): P&D 1906,0509.1.3; PRN: PDB353

09/03/12

## Introduction

1906,0509.1.3 (Figure 1) is a watercolour map of the east coast of North America from Chesapeake Bay to Cape Lookout produced between 1585-1593 by John White, an Elizabethan gentleman and artist who was associated with Walter Raleigh in his attempts to establish a colony in the New World. It forms part of a body of work depicting scenes from the New World which were included in the exhibition 'A New World: England's first view of America' held at the British Museum (BM) in 2007 (Sloan 2007). The results of technical examination of a number of John White's drawings (although not this one) are reported in Bescoby *et al.* 2007 and Ambers *et al.* 2008.

The BM's drawings by John White are known to have been involved in a fire and as a result were soaked in water. Much offsetting of pigments has therefore occurred in the collection. On this sheet the top half has clearly been folded as offsets of the uppermost coat of arms or shield, the compass rose and much of the coastline are visible.

Two patches have been applied on to the surface of the original sheet. There is no evidence of any damage underlying the patches and they seem to have been used to alter or correct features in the original layout, a common practice at this period. In 2012 Dr Brent Lane, of the First Colony Foundation, suggested that the patches might merit investigation and technical imaging and X-ray fluorescence (XRF) and Raman spectroscopy were therefore undertaken.

## Observations

Detailed images of the two patches are shown in Figures 2–5. In both cases the paper used for the patches is torn or jaggedly cut.

The paper of the patches was examined using transmitted light from a light box. It was difficult to fully visualise the laid and chain lines of the patches because they overlie those of the original sheet, but in both patches they appear to have similar characteristics to those in the main sheet in terms of distribution and thickness. Optical microscopy showed the surface of the paper of the patches to be the same in appearance as the paper of the map and also revealed that the application of watercolour pigment on Patch 1 (Figure 2) travels smoothly across the underlying main sheet and onto the patch.

While the surface of Patch 1 appears to be covered by similar watercolour painting as found on the main map sheet, no painting or drawing is immediately obvious on Patch 2 (Figure 4). However on closer inspection a number of light brown lines can just be made out on the surface (see the Discussion section below for further details). Examination with raking light showed no disruption to the paper surface in the area of these lines and under magnification no evidence of applied pigment particles could be found. Under optical examination the brown lines look most like stains or areas of slightly degraded paper fibres.

The patches are securely fixed to the underlying sheet and could not be removed without risk to the surface of the object. The map was therefore examined using non-destructive and non-contact imaging and analytical techniques to investigate the patches, what they might conceal and the pigments used. It was not possible to identify the adhesive used to hold the patches in place as destructive sampling would have been required.

## Methodology

### ***Imaging***

All images (with the exception of infrared reflectograms; see below for details) were collected using a Canon 40D camera body modified by removal of the inbuilt UV-IR blocking filter. This allows the full sensitivity range of the CMOS sensor (c.300–1000 nm) to be used. The lens used was a Canon EF 50 mm f/1.8II. The wavelength ranges required for particular applications were selected by placing a filter or a set of filters in front of the lens. Results are shown below (Figures 2–23).

#### ***Visible imaging***

Visible imaging was undertaken both in reflection and in transmission. Illumination for reflected imaging was provided by two Classic Elinchrom 500 Xenon photographic flashlights equipped with softbox diffusers, which were positioned symmetrically at approximately 45° with respect to the focal axis of the camera. The flashlights have an independent tungsten modelling lamp that produces a considerable amount of infrared and visible radiation, while the ultraviolet component is negligible. Illumination for the transmission images was provided by a light box. An interference UV-IR blocking filter IDAS-UIBAR filter (bandpass, c.380–700 nm) was placed in front of the lens.

#### ***Infrared-reflected imaging***

The light sources used for infrared-reflected imaging were identical to those used for visible-reflected imaging. The visible component is blocked by a Schott RG830 glass cut-on filter (50% transmission at 830 nm). The range under investigation is therefore c.800–1000 nm. IR false-colour images were produced by splitting the visible image into its red, green and blue (RGB) components and shifting the red and green components into the green and blue channels respectively. The values from the IR image were then inserted into the red channel.

#### ***Ultraviolet-reflected imaging***

The radiation source used consisted of two sets of four Philips PL-S 9W double BLB fluorescent lamps passed equipped with Schott DUG11 interference filters (bandpass c.280–400 nm). The emission of the radiation sources is a relatively sharp line centred at 365 nm. The radiation sources were symmetrically positioned at approximately 45° with respect to the focal axis of the camera. UV false-colour images were produced by shifting the blue and green channels of the visible image into the green and red channels respectively and inserting the values of the UV image into the blue channel.

#### ***Ultraviolet-induced (visible) luminescence imaging***

The radiation source used for UV-induced luminescence imaging was identical to the source used for UV-reflected imaging. For the excitation source a Schott DUG11 filter was used and for the emission a combination of Schott KV418 and IDAS-UIBAR filters that transmitted in the visible range (400–700 nm). The Schott KV418 filter is a cut-on filter with 50% transmission at 418 nm. The pre-set white-balance chosen for the camera for this type of imaging – where no identification of pigments was attempted – was 6500 K.

#### ***Infrared reflectography***

Infrared reflectograms were captured using an Osiris Imaging System, manufactured by Opus Instruments, UK, with an InGaAs array (sensitivity c.800–1700 nm) and a six-element 150 mm focal length f/5.6 – f/45 lens. A Schott RG830 glass filter was positioned in front of the lens. Two tungsten radiation sources were positioned at approximately 45° with respect to the focal axis of the camera.

#### ***Image processing***

Selected images were further enhanced using the image processing package VIPS/nip

(Martinez and Cupitt, 2005). Two enhanced versions of the transmitted light image of the symbol underlying Patch 2 were produced, one (Figure 24) by simply scaling the lightness of the uncalibrated image. For the other (Figure 25) the image was converted to the CIE LCh (lightness, chroma and hue) colour system and the h band (hue angle) extracted and scaled. This gives very strong differentiation between the red and blue areas in the concealed symbol, particularly after scaling of the image.

Two methods were applied to increase the legibility of the very faint symbol on the surface of Patch 2, both working from the uncalibrated UV-reflected image. For the first (Figure 26) the lightness was simply scaled to give an optimum visibility of the faint lines that could just be seen by eye. For the second (Figure 27) this image was further processed by local histogram equalization.

## **Analysis**

### *X-ray fluorescence spectroscopy (XRF)*

XRF analysis was carried out directly on to the surface of the map without sampling using a Bruker Artax spectroscopy, fitted with a molybdenum X-ray tube and operated at 50 kV and 0.5 mA. The analytical spot size was c.0.65 mm in diameter and spectra were collected for 300 seconds. The air immediately above the area of analysis was displaced by a gentle stream of helium gas to allow greater sensitivity for lighter elements. The map was supported during analysis in such a way that there was an air space beneath it, rather than resting it directly on a surface as otherwise elements from the supporting surface might be included in the analysis.

### *(Micro-)Raman spectroscopy*

Raman spectroscopy was carried out directly on to the surface of the map without sampling using a Jobin Yvon LabRam Infinity spectroscopy with green (532 nm) and near infrared (785 nm) lasers with maximum powers of 2.4 and 5 mW at the sample respectively (although in general lower powers were used), a liquid nitrogen cooled CCD detector and an Olympus microscope system. This allowed tiny areas containing one or two grains of material to be targeted for analysis with a sample spot size in the order of a few microns in diameter, depending on the power of objective lens used. Spectra were collected for between 5 and 20 seconds, with at least five scans used to produce each spectrum. The resultant spectra were identified by comparison with a British Museum in-house database.

## **Results and discussion**

### **Imaging**

#### ***Main sheet of the map***

Infrared radiation (IR) is generally more penetrative than visible light. Under certain conditions it can be used to visualise areas concealed by overlying materials which are opaque to visible light but transparent to IR. In the art field this is most often applied to the examination of underdrawings in paintings; IR penetrates many pigments but not carbon, and so preliminary sketches made in carbon-based media, such as charcoal or carbon-based inks, concealed beneath paint layers can be revealed in IR images. For this map White used natural graphite, a fairly pure carbon, (see below for details of materials identification) for much of his initial sketching and thus his initial underdrawing is generally clearer in the IR reflectograms (IRR). Examination of the IRR images of the main map sheet reveals many changes between initial sketching and final appearance, although most are fairly minor and relate to geographical detail (see for example Figure 6). Many of the ships

also feature such *pentimenti*. The biggest change, brought to our attention by Dr. Eric Klingelhofer, of the First Colony Foundation, seems to be to the ship in the inlet just to the east of Patch 2. Figure 7 shows a comparison between the final version of this vessel and the initial sketch or underdrawing as revealed in the IRR. In the IRR the ship has two lines to the side which could be oars or anchor ropes and the sail seems to be billowing towards the land, while in the final image the lines have been covered with the brown paint used to depict the ship's hull and the sail seems to bow in the opposite direction. On close examination, the faint square lines around the sail and the line extending from the body of the ship on the right seem to relate to the pigments of the final version of the ship rather than to underdrawing. Smaller changes can be seen in other vessels (see for example Figure 8 for images of the two ships to the east of Patch 1) although these seem to relate mostly to the sails or the rigging. There are even faint traces of what may be a ship which was sketched but never actually painted in (Figure 9).

### **Patch 1**

The number of alterations between the initial sketches and the final image on the main map sheet add to the complications of interpreting what may lie beneath Patch 1. Comparison of the visible reflected and transmitted images (Figures 2 and 3) suggest it covers a very similar earlier version of this area of coastline but at least two blue lines, crossing the peninsula on which Seco sits, and possibly others, exist in the transmitted light image (Figure 3) which are not replicated in the reflected light image (Figure 2) and must therefore relate to the drawing concealed by the patch. These may reflect a differently shaped coastline or additional river courses present in the original version. The infrared images (Figures 11 and 12) certainly show extensive changes to many areas of the patch but it is not clear how far the IR has penetrated and hence how many of these alterations relate to changes to preliminary sketching made on top of the patch and how much to changes from the earlier version underneath it. Probably the best clue to interpreting the images can be obtained from the outline of the original location marker spot for Secotaóc (which was repositioned to the west in the final image) which is half concealed by the patch. The original location marker is very visible in the IR reflectogram (Figure 12) where it protrudes from beneath the patch and is just barely visible (if at all) where covered. On this basis it seems most likely that the majority of the black lines visible in the IR images relate to preliminary sketching on the top surface of the patch rather than to the drawing concealed beneath the patch. It is therefore difficult to be sure what lies under the patch and hence why it was applied. The answer may simply relate to the blue lines which do clearly underlie it. The evidence of multiple changes from the initial sketch lines found on the main map sheet shows how simple it was to correct mistakes in the graphite sketch lines, largely by just painting over them. It is possible that the blue paint lines, however, were more difficult to modify and it may have been easier to simply cover them.

### **Patch 2**

For Patch 2, the visible transmitted image (Figure 5) shows that it covers a very different earlier version, featuring a large lozenge or four pointed star-shaped symbol, outlined in blue and filled with red. The two leftmost points of this shape can just be seen on the surface of the main map protruding from under the left hand edge of the patch, and appear to have been painted using a blue pigment with a similar appearance to that used for the coastline and sea. A small circle (fully concealed by the patch) can also be seen to the right of this shape, next to the coastline.

Image processing as described above has made it possible to enhance the detail of the lozenge or star-shaped symbol (Figures 24 and 25). In Figure 24 a dark feature (possibly the outlines of a square) can be made out in the centre of the symbol. From Figure 25, it

appears that the inner (red) section (which shows as dark given this processing) has defined sub-rectangular corners at the top.

On the surface of this patch a similar, but smaller lozenge or star shape can be seen faintly in the visible reflected image (Figure 4), possibly surrounded by one or more squares. This design is revealed slightly more clearly in the UV-reflected image, suggesting it is a surface feature or phenomenon, as UV is less penetrative than visible light (Figure 21). This symbol has been further enhanced by processing the UV-reflected image as described above (Figures 26 and 27). Here the lozenge or four pointed star shape similar to but smaller than that found under the patch is more apparent. It appears to have a central cross shaped feature (although interpretation of this is complicated by a horizontal fold line which passes through the centre of both patch and symbol) and to be surrounded by two concentric squares, incomplete on the coastal side

## Pigment Analysis

A number of areas of the map were analysed using XRF and Raman spectroscopy to identify the pigments present.

The areas studied with XRF are shown in Figure 28 and the results tabulated in Table 1. XRF analysis provides information on the elements present in the area analysed. With the XRF equipment available it is not possible to detect very light elements, so that organic materials cannot be identified using this method and aluminium is poorly recorded. The X-rays penetrate the thin pigment layers (and also the paper of the patches) and the results collected therefore include information from the pigments, the underlying paper and from material beneath the patches. This means it is necessary to analyse an unpainted area of the paper (in this case XRF site 1 for areas of the main map) and use this to deduct the substrate contribution from the results. When Patch 2 was analysed two areas of the patch away from any known pigment contribution either from the top surface or from the underlying painting (XRF sites 2 and 6) were measured to act as the control.

The areas studied with Raman spectroscopy are shown in Figure 29 and the results tabulated in Table 2. Raman spectroscopy can provide compound-specific identifications for Raman active materials. These include most inorganic and some (although by no means all) organic pigments.

Because of the water damage to the album of John White drawings (discussed above), some transfer of material from drawing to drawing may have occurred and hence a high proportion of contaminant traces may be expected (Ambers *et al.* 2008).

XRF of an area of blank paper on the main sheet (XRF site 1) gave a range of elements typical of what is expected for paper of this type. The blank areas of paper of Patch 2 (XRF sites 2 and 6) contained a slightly wider range of elements, including small amounts of copper, lead and mercury. When examined at high magnification under the Raman microscope a number of diffuse red grains were found scattered across the paper of the patch. These produced spectra characteristic of vermilion (HgS; Raman site R4), thus explaining the presence of mercury at above background levels in this area. There is no evidence that this vermilion was deliberately applied or follows any pattern, and it is most likely to be due to contamination of the paper, something which could happen easily within an artist's studio.

Raman spectra collected from a black line of underdrawing (Raman site R1) showed it to be carbon. A clear strong peak at  $1580\text{ cm}^{-1}$  indicated that graphite was used.

XRF of the blue pigment of the symbol under Patch 2 where it slightly protrudes from beneath the patch (XRF site 3) showed no elements other than those found in the paper, suggesting the use of an organic pigment. This was confirmed by Raman analysis (Raman site R7) which produced spectra for indigo. Raman spectroscopy of the blue of the coastline (Raman sites R2 and R14) gave the same results. This confirms the conclusion drawn on the basis of visual examination that the same blue pigment is used for the main map, on the surface of Patch 1 and for the symbol under Patch 2.

The lower coat of arms or shield currently features two colours, red and black. The red area (XRF site 7) contains high levels of both mercury and lead, while Raman spectroscopy (Raman site R8) confirmed the presence of vermilion and red lead. The black areas (XRF site 8) contain high levels of silver, and are interpreted as representing the use of metallic silver which has now degraded.

The areas of red in the concealed symbol under Patch 2 (XRF sites 4 and 5) contain a high proportion of lead suggesting the use of red lead ( $\text{Pb}_3\text{O}_4$ ). No evidence was found of the use of gold or silver in this area.

As discussed above, the sheet was once folded. Much of the surface of the second coat of arms or shield, towards the top of the sheet, has been offset onto the area above it and under magnification it is clear that much pigment, including fine detail, has been lost. The quarters which now appear mostly white were originally blue with gold coloured symbols applied over the top. XRF analysis of the remaining gold (site 9) and blue (site 11) areas show high levels of arsenic and cobalt respectively. Raman analysis of a gold area (Raman site R5) confirmed the use of the pigment orpiment ( $\text{As}_2\text{S}_3$ ), which is both gold in colour and gold-like in lustre. Orpiment is not commonly found on paintings of this period, as it is photosensitive and is also unstable in combination with many other paints but Harley (1982) records that it was considered suitable for heraldic devices. The cobalt must represent the use of a cobalt-containing blue colourant. Given that potassium and silicon were also detected this is most likely to be the potassium-containing glassy pigment smalt which was in common use during this period. No elements above the paper background levels were detected in the outline of this shield and this combined with the IR imaging results, suggests that the material used is carbon-based.

The ship to the east of Patch 2 (Raman site R9) was found to have been painted with a mixture of a black material (unidentified) and hematite. Under the high magnification of the Raman equipment the diffuse red paint used in the islands of the Outer Banks could be seen to be coloured with a mixture of two pigments, one with fine dark red grains and the other with irregular glossy pink transparent particles. The dark red material was found to be vermilion (Raman site R11) while the pink particles (Raman site R12) gave no Raman spectrum and are tentatively identified as a possible red lake pigment.

The pigment used for two of the location marker spots, one on the main map sheet slightly to the south of Patch 2 (site R10) and one on top of Patch 1 (site R13), were also examined using Raman spectroscopy. Spectra could not be produced for either and this, together with the appearance of the pigment grains, suggests use of a red lake pigment.

All of these pigments are typical of those used in the Elizabethan period and, with the exception of orpiment, all have been found in other watercolours by White (Bescoby *et al.* 2007 and Ambers *et al.* 2008).

Analysis of the very faint lines on top of Patch 2 was problematic, both because the lines are

narrow and also because of difficulties in visualising them. However, two areas where the lines appear most dense, and where as little as possible of the underlying symbol was in the beam path, were analysed by XRF (XRF sites 13 and 14). This did not reveal any elements present at levels above what would be expected from the underlying paper, paper patch and concealed symbol. Similarly two areas where the brown lines are present were analysed by Raman spectroscopy (Raman sites R3 and R6) and no Raman spectra could be produced. As noted above, when examined by optical microscopy, the lines give the impression of being stains or areas of localised damage rather than being due to the deliberate application of a particulate pigment (no coherent pattern of particles can be seen even at high magnification) and the image is clearest under UV illumination suggesting that it is a surface feature. These results are difficult to interpret; it seems most likely that the lines are due to the application of an organic material (but not carbon or graphite, both of which have clear Raman responses) but no firm conclusion can be reached. Indigo, an organic pigment, has already been securely identified on this drawing, but in particulate form and with apparently stable colour. Other organics are certainly present in other paintings by White; within the BM collections a much faded green is used in *Sabatia* (P&D 1906,0509.1.38) along with organic-based pink and purple colourants that are rather better preserved. However these seem to have been applied within graphite outlines and none of the organic pigments so far examined in the BM laboratory have quite the same appearance as the lines observed here. One other possible, if rather romantic, explanation is that these lines could reflect the use of an 'invisible' ink (an ink which would only be revealed when treated in some way, usually by applying heat). Such materials are well recorded from this period, with inks based on alum, milk, citrus juice or urine being the most frequently mentioned (Cooper, 2011, quoting Gregorie and TNA 12/156). The data to date would certainly be consistent with the use of any of the materials in this list, even alum; while no aluminium was recorded in the areas examined, the low sensitivity of the XRF equipment to aluminium means that its use cannot be excluded. However, such a specific hypothesis is impossible to prove and the use of an initially visible, but now much faded, substance is probably more likely.

J. Ambers

J. Russell

D. Saunders

A. Rugheimer

## References

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Table 1. XRF results for 1906,0509.1.3

Spot no.	Area	Elements present*	Interpretation
1	Blank area of paper	Si(tr), S(tr), Mn(tr), Zn(tr), Pb(tr), Sr, Fe, Ca+	
2	Blank area of Patch 2 (area away from the symbol and with no colour beneath)	Si(tr), S(tr), Mn(tr), Zn(tr), Pb, Sr, Cu, Hg, Fe, Ca+	
3	Blue from underlying symbol at edge of Patch 2	Si(tr), S(tr), Mn(tr), Zn(tr), Pb, Sr, Cu, Hg, Fe, Ca+	Organic material – no detectable elements above the paper background. Probably indigo
4	Area of Patch 2 above blue/red in underlying symbol	Si(tr), S(tr), Mn(tr), Zn(tr), Sr, Cu, Hg, Fe+, Ca+, Pb++	Red lead
5	Centre of Patch 2, above red in underlying symbol	Si(tr), S(tr), Mn(tr), Zn(tr), Sr, Cu, Hg, Fe+, Ca+, Pb++	Red lead
6	Area of Patch 2 (area away from the symbol and with no colour beneath)	Si(tr), S(tr), Mn(tr), Zn(tr), Hg(tr), Pb, Sr, Cu, Fe, Ca+	
7	Red area of bottom coat of arms	Si(tr), Mn(tr), Fe, Cu, Sr, Ca, S, Hg++, Pb++	Vermilion mixed with either red or white lead or with a white lead ground
8	Black area of bottom coat of arms	Si(tr), Mn(tr), Fe, Cu, Sr, Ca, S, Zn, Ag+, Hg++, Pb++	Degraded metallic silver over red (as above)
9	Gold on blue area of top coat of arms	Si(tr), Mn(tr), S, Si, K, Ca, Ni, Cu, Zn, Bi, Pb, Fe+, Co++, As++	Orpiment over smalt
10	Black area of top coat of arms	Si(tr), S(tr), Mn(tr), Zn(tr), Pb(tr), Sr, Fe, Ca+, Pb	Organic material – no detectable elements above the paper background. Carbon-based material on the basis of the IR images
11	Blue area of top coat of arms	Si(tr), Cu(tr), Zn(tr), S, K, Ca, Sr, Ni, Bi, Pb, Fe, Co++, As++	Smalt (with traces of orpiment from overlying design)
12	Red area of top coat of arms	Si(tr), Mn(tr), Cu(tr), S,	Vermilion mixed with either

		Sr, Zn, Ca, Fe, Hg+, Pb+	red or white lead or with a white lead ground
13	Faint brown line on top of Patch 2 (area away from the underlying symbol)	Si(tr),S(tr), Mn(tr), Pb, Sr, Cu, Hg, Fe, Ca+	?organic material or degradation of cellulose fibres
14	Faint brown line on top of Patch 2 (area away from the underlying symbol)	Si(tr),S(tr), Hg(tr), Pb, Sr, Cu, Fe, Ca+	?organic material or degradation of cellulose fibres
15	Area of Patch 2 above dark circle next to coast	Si(tr),S(tr), Hg(tr), Pb, Sr, Cu, Fe, Ca+	?organic material
16	Red spot marking 'Chawanoac'	Si(tr),S(tr), Hg(tr), Al, Sr, Cu, Fe, Ca+, Pb ++	Red lead

\*Where a chemical symbol is given alone this represents a detected presence, tr indicates trace, and + and ++ indicate increasing abundance.

Table 2 Raman results for 1906,0509.1.3

Spot no.	Area	Raman result	Interpretation
R1	Black line of underdrawing near the coast	graphite	graphite
R2	Blue line around the coast (main map)	indigo	indigo
R3	Brown lines on surface of Patch 2	no spectrum recorded	no identification
R4	One of the scattered red grains in the paper of Patch 2	vermilion	vermilion
R5	Yellow symbol in the upper coat of arms	orpiment	orpiment
R6	Brown lines on surface of Patch 2	no spectrum recorded	no identification
R7	Blue on the main map sheet where the large symbol under Patch 2 protrudes from the patch	indigo	indigo
R8	Red on the lower coat of arms	vermilion and red lead	mixture of vermilion and red lead
R9	Red of boat to east of Patch 2	no spectrum	?red lake pigment
R10	Red of location marker spot	no spectrum	?red lake pigment

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	south of Patch 2		
R11	Dark red grains in chain of islands	vermilion	vermilion
R12	Pinky/red grains in chain of islands	no spectrum	?red lake pigment
R13	Red of location marker spot on top of Patch 1	no spectrum	?red lake pigment
R14	Blue line on top of Patch 1	indigo	indigo



Figure 1: 1906,0509.1.3, showing the positions of the two patches



Figure 2: Reflected visible light image of Patch 1





Figure 3: Transmitted visible light image of Patch 1



Figure 4: Reflected visible light image of Patch 2





Figure 5: Transmitted visible light image of Patch 2



Figure 6: Area to the east of Lake Paquippe showing changes between the initial sketching, as shown in the IR reflectogram (left) and the finished map, as shown in the visible image (right). Once alerted by the IRR image to the changes, many can in fact be recognised in the

visible image.



Figure 7: Images of the ship in the inlet just to the east of Patch 2; left, underdrawing as revealed in the IR reflectogram; right, final painted image



Figure 8: Images of the ships to the east of Patch 1; left, underdrawing as revealed in the IR reflectogram; right, final painted image





Figure 9: Images of the centre right of the map showing what is possibly a sketched ship that was never finalised; left, underdrawing as revealed in the IR reflectogram; right, final painted image



Figure 10: Reflected visible light image of the region containing Patch 1



Figure 11: Infrared reflected image (800–1000 nm) of the region containing Patch 1



Figure 12: Infrared reflectogram (800–1700 nm) of the region containing Patch 1

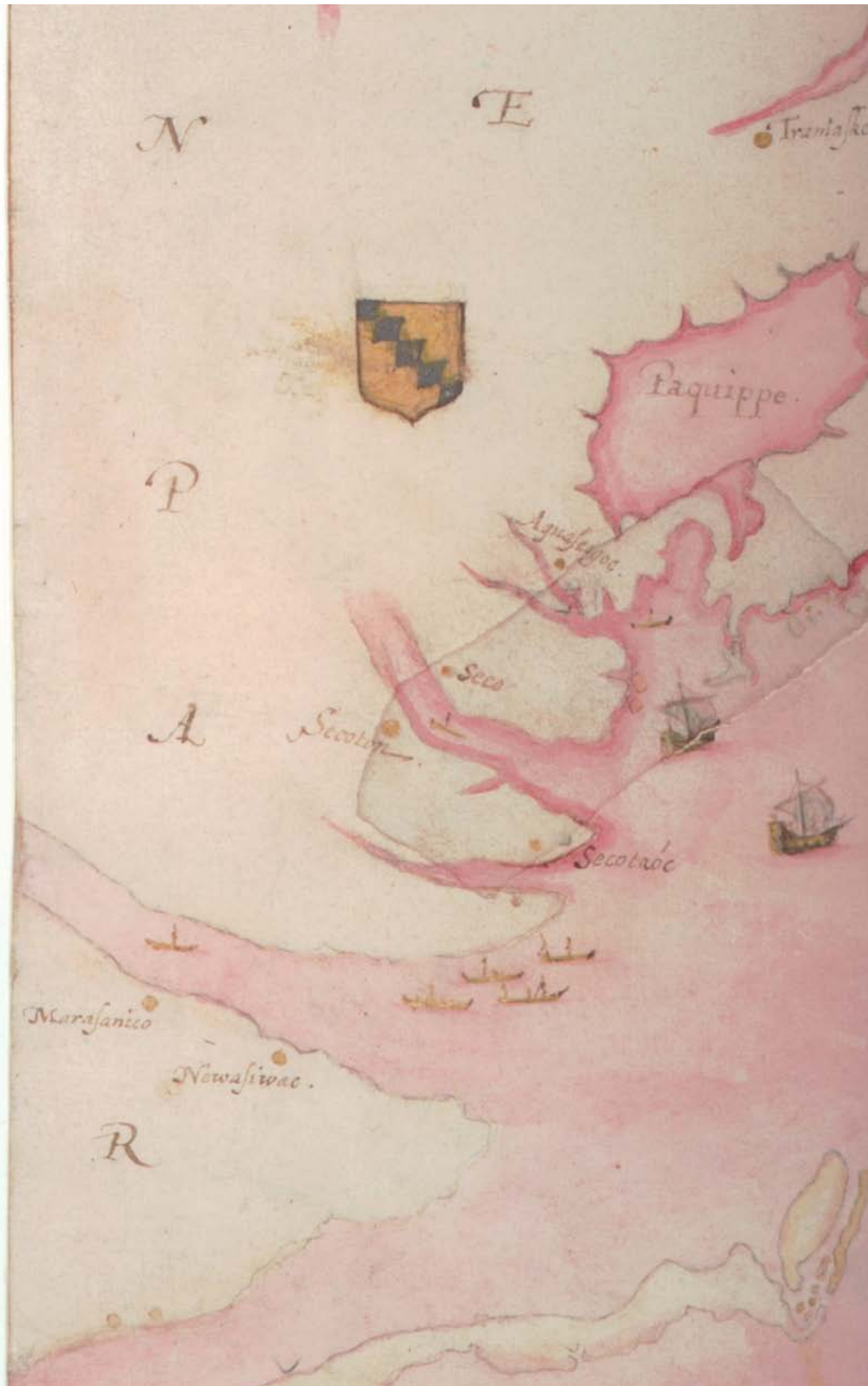


Figure 13: Infrared false-colour image (800–1000 nm) of the region containing Patch 1





Figure 14: Ultraviolet reflected image (365 nm) of the region containing Patch 1





Figure 15: Ultraviolet reflected false-colour image (365 nm) of the region containing Patch 1

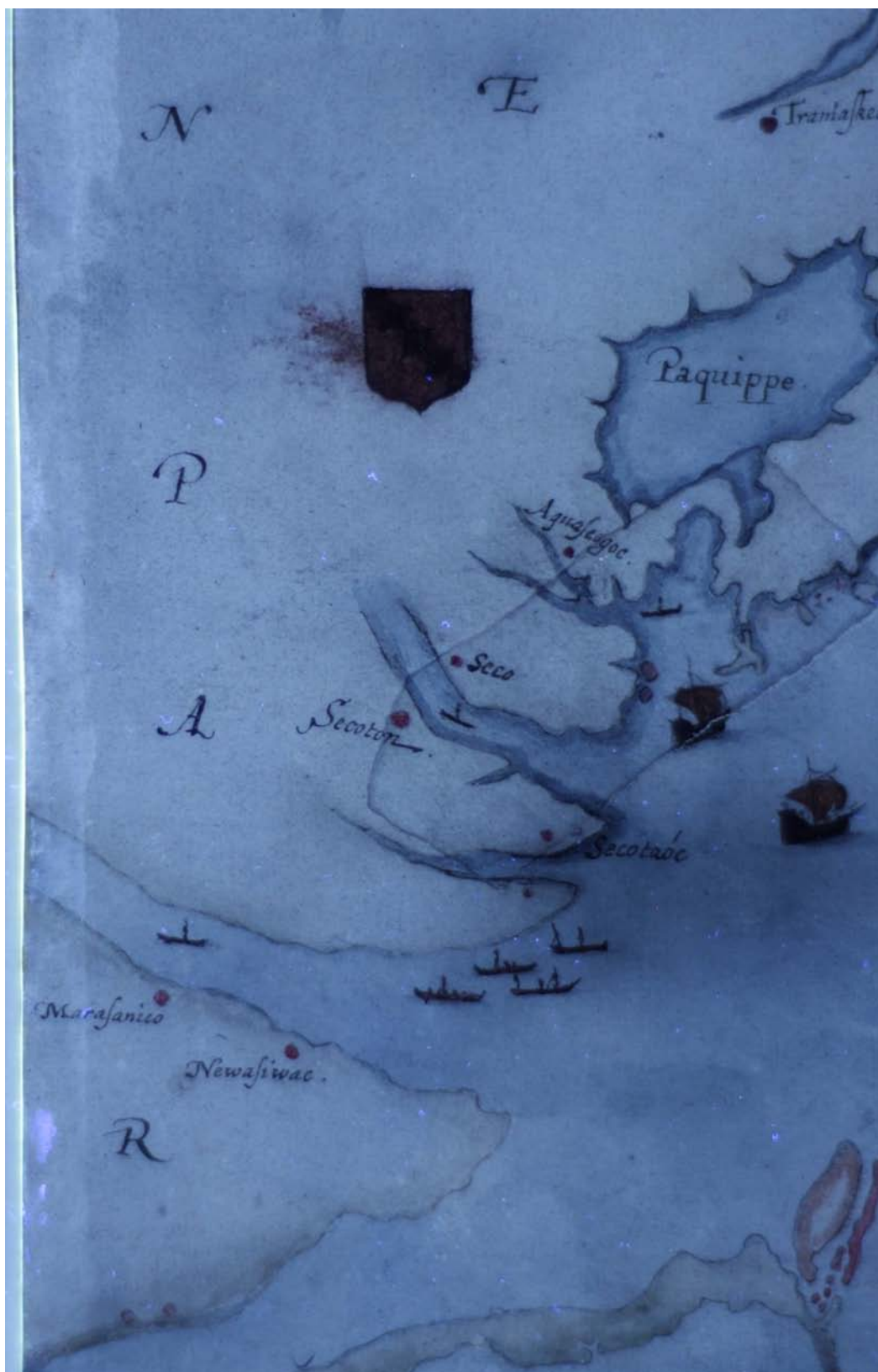


Figure 16: Ultraviolet induced luminescence image (365 nm) of the region containing Patch 1



Figure 17: Reflected visible light image of the region containing Patch 2



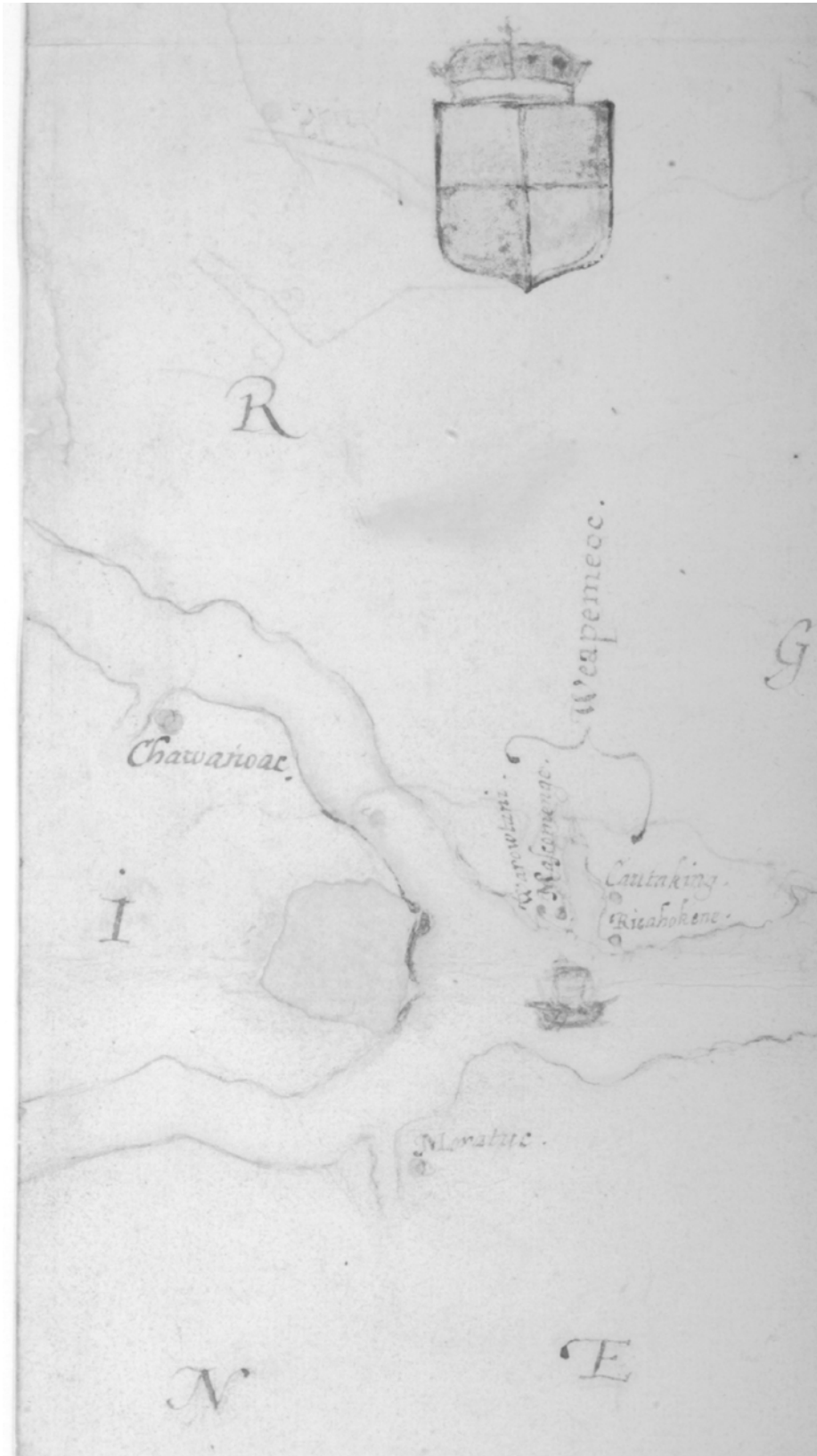


Figure 18: Infrared reflected image (800–1000 nm) of the region containing Patch 2

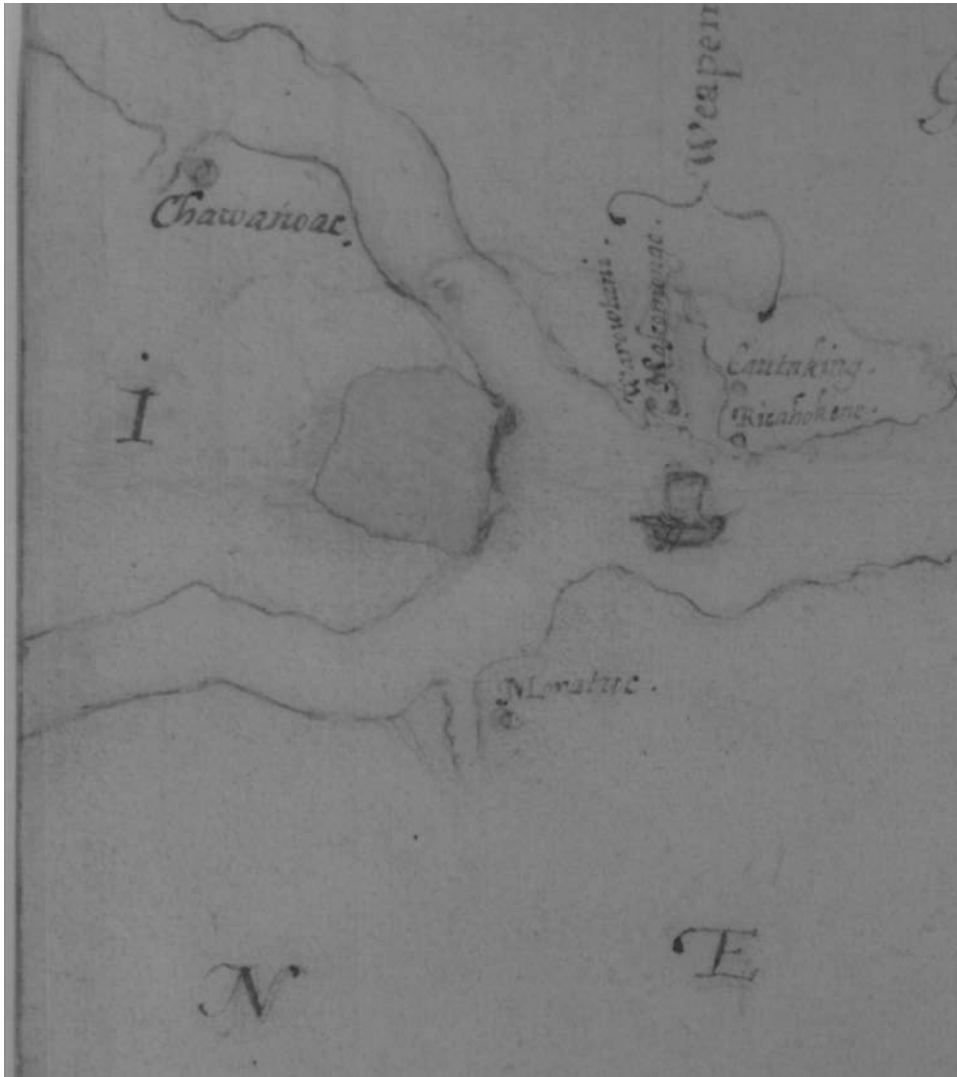


Figure 19: Infrared reflectogram (800–1700 nm) of the region containing Patch 2



Figure 20: Infrared false-colour image (800–1000 nm) of the region containing Patch 2



Figure 21: Ultraviolet reflected image (365 nm) of the region containing Patch 2



Figure 22: Ultraviolet reflected false-colour image (365 nm) of the region containing Patch 2





Figure 23: Ultraviolet induced luminescence image (365 nm) of the region containing Patch 2

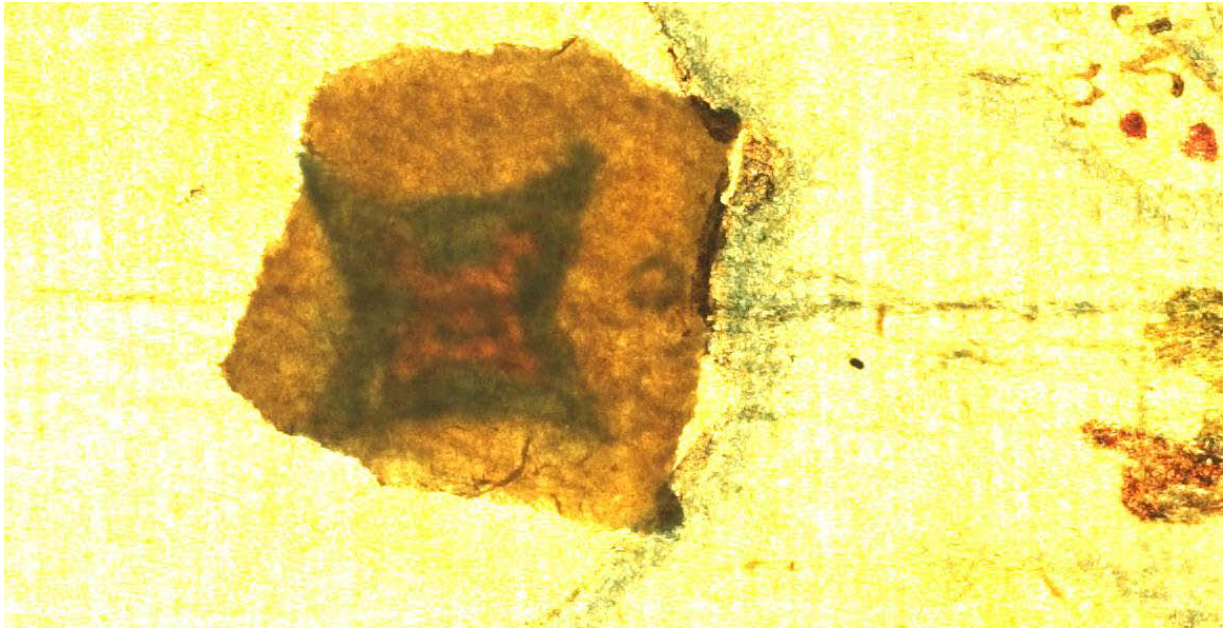


Figure 24: Enhanced image of symbol underlying Patch 2 produced by scaling the lightness of the transmitted visible light image.



Figure 25: Enhanced image of symbol underlying Patch 2 produced by converting the transmitted visible light image into the LCh system and extracting and scaling the h band.



Figure 26: Enhanced image of symbol on surface of Patch 2 produced by scaling the lightness of the UV-reflected image.

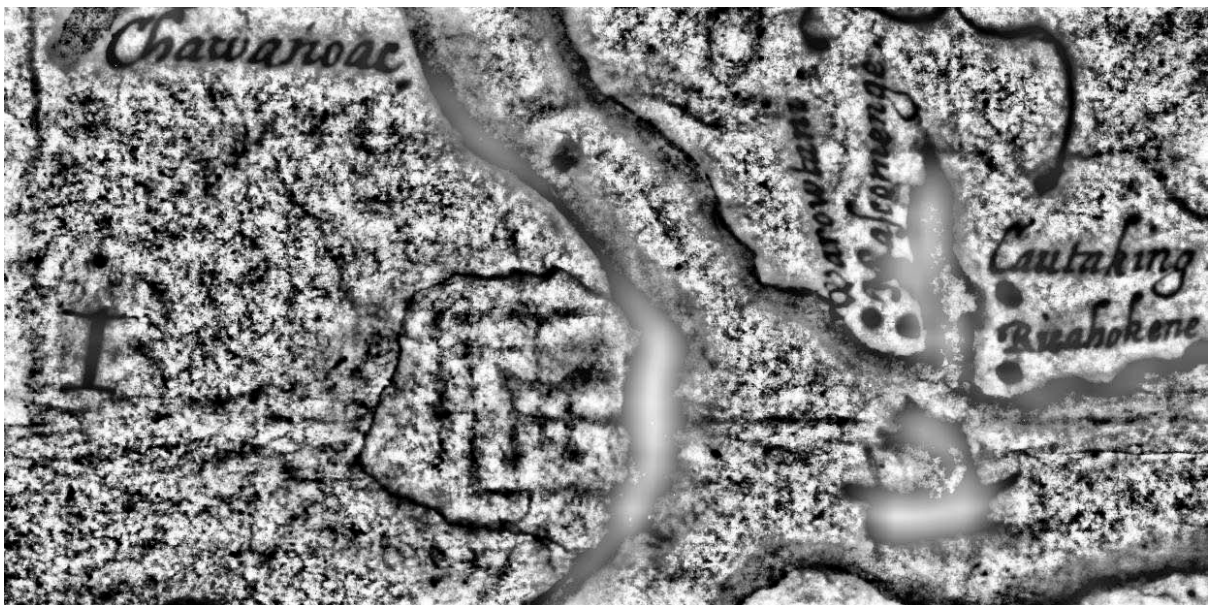


Figure 27: Enhanced image of symbol on surface of Patch 2 produced by local histogram equalization of the scaled UV-reflected image.





Figure 28: Locations of sites analysed using XRF



Figure 29: Locations of sites analysed using Raman spectroscopy