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Looking at Wilson's Paintings of the Antarctic

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Dr Edward A. Wilson was a member of the 'Discovery' expedition to the Antarctic in 1901–04 and the 'Terra Nova' expedition 1910–13, both of which were led by Captain Robert Falcon Scott. He made a visual record of what he saw, by sketching in daylight and painting in watercolour at night in the winter base hut illuminated by the light of acetylene gas lamps. The paintings have survived, but when viewed under daylight now they may look quite different from what Wilson saw. We have measured the spectrum of the gas lighting and digitised the paintings with a hyperspectral image scanner to investigate the effects of chromatic adaptation.

Antarctic expedition, Painting, Acetylene illumination, Hyperspectral scanner, Chromatic adaptation

1. WILSON'S ANTARCTIC PAINTINGS

Scientific expeditions of the early 1900s into the hitherto unseen interior regions of Antarctica utilised established and emergent technologies to document the environment, its wildlife and meteorological phenomena. Multiple media – pencil sketches, watercolours, journals and photographic materials – were employed to record the scientific work of the expedition, to illustrate official expedition narratives. They also sought to recuperate the costs of exploration through public exhibition in art galleries and as lantern slides and cinematograph lectures (Watkins 2018).

Two Antarctic expeditions were led by Captain Robert Scott: the British National Antarctic Expedition on the 'Discovery' 1901–04 and the ill-fated British Antarctic Expedition on the 'Terra Nova' 1910–13. The explorers overwintered in different locations, the 'Discovery' on board the ship which was trapped in ice 1902–04 and Scott's second expedition at Cape Evans. In each case, an acetylene gas plant was built to produce acetylene gas by dripping water onto calcium carbide. In May 1903 Scott recorded in his diary: 'our acetylene plant is now in full swing and gives us light for twelve hours at an expenditure of about 3lbs of carbide' (Scott 1907).

Dr Edward Wilson was a member of the scientific staff on both expeditions. He was a physician, fellow of the Zoological Society, ornithologist, and artist who had illustrated several books about wildlife. He died in March 1912 on the return journey from the South Pole, along with Scott, Oates, Bowers and Edgar Evans. His pencil sketches, watercolours and original manuscripts are kept at the Scott Polar Research Institute (SPRI), Cambridge. Wilson's pencil sketches of shifting coastlines, ice formations and geographical features contributed to the cartography of the region. As a skilled colourist, his black and white pencil sketches were annotated with notes regarding the hues of his subjects (Fig. 1). Colour could assist the identification of wildlife and geology of the region and studies of Aurora Australis, paraselena and other optical effects of light refracted by the ice. Colour offered a multifaceted yet often elusive topic for study, utterly dependent on light conditions in a region characterised by extremes of temperature and months of darkness in winter; as spectacle, moreover, colour enhanced the potential for public exhibition.

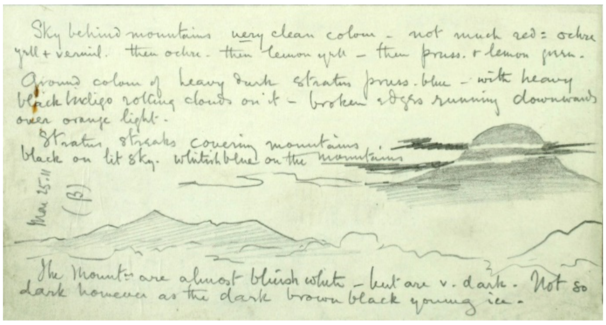

Figure 1: *Pencil sketch by Wilson of mountain in clouds, with colour notes, 25 March 1911. SPRI Cat. N1802/4*

Wilson's notebooks include numerous references to issues encountered in the study of colour. In sketching from direct observation he found chalks impracticable for the accumulation of dirt, whilst watercolours froze to the page. Experiments with colour photography were lost or deemed unsuccessful, such as those of Reginald Koettlitz on the 'Discovery' expedition. Wilson developed a working process of 'colour note sketches' – black and white pencil drawings annotated with generic colour names (red, yellow) – which he would subsequently use to inform the painting of watercolours (Savours 1966).

Evening work in the Winter Base Hut necessitated the use of artificial light sources, particularly during the three months of darkness that characterise Polar winter. Wilson commented that oil lamps and candles provided insufficient illumination for substantial work, until the introduction of acetylene gas as a source of light (Fig. 2). His diary for 1903 includes the following entries:

> Friday 10th April: 'Acetylene gas is being tried now, and gives an excellent light, if only the machine making it will not succumb to the cold in the lobby, as water has to be used.' (p.254)
>
> Thursday 23rd April: 'Calm clear day, perfect weather. Colour everywhere. Went up the Harbour Hills. Erebus' smoke was lit up with a fiery orange light by the set sun. The blue on the southern and western horizon rising into lilac and rose pink was exactly what one sees in the Swiss winter. Here, now that the sun is below the horizon, one sees the shadow of the slopes of Erebus thrown against the sky in a pure blue on the south-west horizon. Afternoon drawing, evening painting by acetylene.' (p.255)
>
> Tuesday 2nd June: 'In the afternoon one can get in about 2½ hours at the table and in the evening, from 7.30 till about 11 when the acetylene gas is turned off and only those who have candles to spare can go on working.' (pp.262-263)

Figure 2: *Herbert G. Ponting's flashlight photograph, printed from a black-and-white orthochromatic glass negative, shows E.A. Wilson painting under acetylene light in the Winter base hut at Cape Evans, 20th May 1911. The table lamp has a conical shade with white enamel on the underside. SPRI Cat: P2005/5/402*

Both Captain Scott and Wilson directly linked the availability of artificial light, such as the rationing of candles, to work and morale. Sources of fuel, for heat and light, included oil lamps, candles, paraffin, acetylene gas, coal, and a wind turbine to generate electricity. Electricity was available on the 'Discovery' expedition until May 1902 when the turbine was damaged in a gale, but was more consistent throughout the 'Terra Nova' expedition. The practicalities of work in the Antarctic, including the peculiarities of acetylene gas light and innovations in electric lighting, often formed the basis of newspaper and journal articles appealing to readers in the modern metropolis.

An exhibition of Wilson's work at the New Archaeological Museum Cambridge in May 1914 included watercolours from the 'Discovery' and 'Terra Nova' expeditions. A review in *The Cambridge Independent Press* describes 'works painted for the most part in the snow hut, lit by a smoky acetylene lamp, with a number of men around doing anything from trimming the blubber lamp to mending harness'. Wilson 'would make a copy of his note sketch, filling in the colours in the places indicated. It is a method that requires a retentive memory of colour effects and an eye unaffected by a light that is eternally altering colour values.' The presence of contaminants, such as coal dust and soot, is visible in the finger prints at the edges of the lampshade in Ponting's 1911 photograph (Fig. 2), further complicating the perception of colour in Wilson's work. The pencil note sketches record scientific observations of wildlife, glaciers, paraselene, Aurora Australis and the colours of light refracted by the ice at sunrise and sunset. The watercolour paintings set scientific observations in a composition that was both cautious and constructed for exhibition and sale to recoup the costs of the expedition.

2. SPECTRUM OF ACETYLENE GAS LIGHT

What did Wilson see when painting his pictures under acetylene gas light? Both the rendering of his colour paints and the adaptation state of his vision depended on the spectral power distribution of the illumination. The method for production of calcium carbide in an electric arc furnace had been discovered in 1892 and quickly became important industrially, using great quantities of power from hydro-electric generators. Calcium carbide reacts with water to produce acetylene gas and calcium hydroxide:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \qquad (1)$$

Calcium carbide found widespread use in carbide lamps, burning the acetylene gas to produce light. Though subject to variations in the purity of calcium carbide, these lamps gave steadier and brighter light than candles, and were employed in mining and caving, and extensively as headlights in early automobiles, motorcycles and bicycles, until improvements in battery technology led to their replacement by electric lamps in the 1920s.

No data on the spectral power distribution of light from an acetylene flame could be found in the literature, so it was measured empirically. A vintage Calcia Major bicycle lamp was purchased, together with a quantity of calcium carbide, and restored to working condition. After reaching stability the flame spectrum was measured with a PhotoResearch PR-650 telespectroradiometer (Fig. 3).

Figure 3: *Measurement of flame spectrum with PR-650*

The data gives the intensity at wavelength intervals of 4 nm over the range 380–780 nm. Three measurements were normalised at 600 nm. The plot of power vs wavelength shows a continuous distribution with a correlated colour temperature (CCT) of 2510K, as expected for the combustion of a hydrocarbon (Fig. 4). Relative to standard Illuminant A (tungsten filament lamp, CCT = 2856K), the spectrum has a little less power in the shorter wavelengths (blue to green) and more power in the longer wavelengths (red into infrared). The calculated CIE general colour rendering index R_a of the acetylene flame spectrum is 99.85, similar to that of Illuminant A.

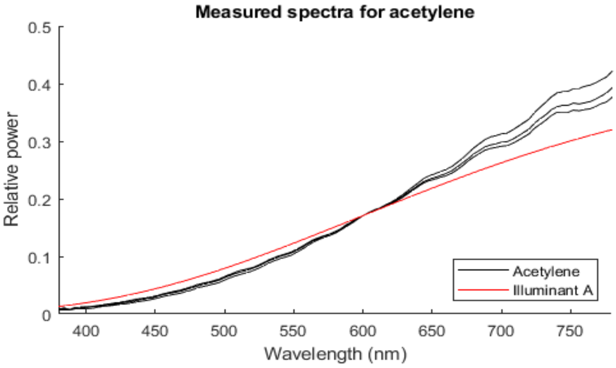

Figure 4: *Measured spectral power distribution of acetylene flame vs Illuminant A*

The yellowish light emitted by the flame and its associated low CCT is caused by the limited amount of atmospheric oxygen available for normal combustion in air. The predominant process is the breakup of acetylene molecules into carbon and hydrogen, with excess carbon deposited as soot:

$$C_2H_2 = C_2 + H_2 \tag{2}$$

If the temperature of the luminous zone is above 1200°C, the light emitted is due mainly to incandescent particles of carbon, and not to incandescent hydrocarbon vapours (Lewes 1894).

Suppose that more oxygen could be introduced into the combustion process? As increasing oxygen becomes available, the main reactions produce carbon monoxide or carbon dioxide and water:

$$2C_2H_2 + 3O_2 \rightarrow 4CO + 2H_2O \tag{3}$$

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O \tag{4}$$

Further experimental measurements were made on the flame from a cutting torch attached to an industrial oxy-acetylene rig in an engineering workshop. The PR-650 was focused on a spot at the centre of the flame (Fig. 5) and the room lights were switched off to make the measurements.

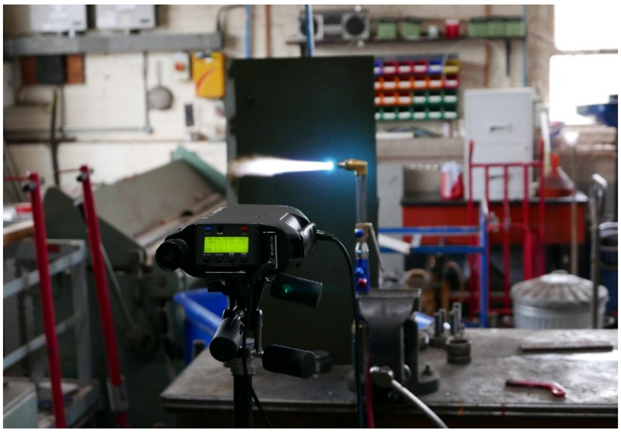

Figure 5: Measurement of an oxy-acetylene flame

Turning on the acetylene gas initially produced an unfocused yellow-orange flame and a shower of soot. As the proportion of oxygen was increased, the flame became hotter and bluer causing the emission spectrum to change shape, with greater power at shorter wavelengths. Fig. 6 shows the family of curves, normalised at 620 nm, plotted for 45 spectral measurements. The baseline curve, for acetylene burning in air without additional oxygen, is similar to that for the cycle lamp in Fig. 4, but with an even lower CCT of 1756K. As oxygen is introduced the chemical reactions of first Eq. 3 and then Eq. 4 become dominant, and the spectrum shifts toward blue, with strong line spectra for C_2 combustion at 473.7, 516.5 and 563.5 nm. The final spectrum in the sequence has the greatest power at short wavelengths (blue to violet) with a CCT of 22844K.

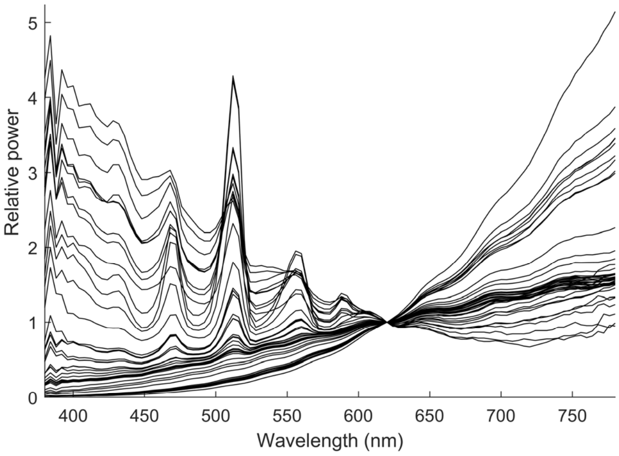

Figure 6: *Relative power vs wavelength for varying proportions of oxygen and acetylene*

3. HYPERSPECTRAL IMAGE PROCESSING

In order to make colorimetric calculations for the paintings under various illumination spectra, it is necessary to know the reflectance spectra of the paintings at every point. Selected paintings by Wilson were scanned at SPRI by a Headwall Hyperspec III scanner (Fig. 7). This produced an image array of 1168 vertical lines of 640 samples, in 270 spectral bands, at intervals of approximately 2.24 nm over the wavelength range 400–1000 nm.

Figure 7: *Dr Francesco Beccari with the Headwall hyperspectral scanner in operation at SPRI*

The image files were stored in ENVI format, each of size 769 Mbyte, with data in single-precision floating point representing the reflectance factor in the range 0-1, calibrated by reference to a spectralon white tile. The spatial resolution on the surface of the painting was 4.5 pixels/mm, i.e. a pixel size of 0.22 mm.

Eight watercolour paintings were scanned, representing Wilson's work in both expeditions. The hyperspectral image sets were processed in Matlab. Colorimetric calculations used the CIE standard 2° observer over the range 380–780 nm, interpolated to the same wavelength intervals as the image data (vector of 170 values). Using CIE standard D65 as the illuminant, the X,Y,Z tristimulus values were calculated and converted to the sRGB colour space for display. For this paper one painting *Earth Shadows* is used as an example (Fig. 8). It is outstanding for the delicacy of colour gradations in the sky, and carefully observed coloration of foreground shadows.

Figure 8: *Watercolour painting 'Earth Shadows' by E.A. Wilson, 24 April 1903 (SPRI Cat. N1288), 200x120 mm*

The tristimulus values were recalculated, using instead the spectrum of the acetylene flame as the illumination source, then converted to sRGB with the D65 white reference. The resulting image has a horribly yellow cast (Fig. 9). This is what an observer fully adapted to D65 would see if viewing the painting illuminated by the acetylene lamp, for example when looking from a room illuminated by D65 through an aperture into a chamber illuminated by acetylene flame. Because there is so little power in the acetylene illumination at short wavelengths, the blues disappear completely.

Figure 9: *Watercolour painting 'Earth shadows' illuminated by light from an acetylene flame*

4. CHROMATIC ADAPTATION

Wilson, when painting at night in the hut, would have been completely adapted to the prevailing illumination, i.e. the light emitted by the gas lamp on his desk and other sources in the room. He noted the effects of this illumination on his perception of colour whilst painting, commenting on the uncertainty of yellows and blues (Savours 1966):

> 'Discovery' Expedition, 12 April 1903: 'Had a game of hockey in the afternoon, otherwise spent the day at the S.P.T. drawings. We had acetylene gas today and I find one can paint by it, though in yellows and blues one cannot tell what one is doing.'
>
> 'Terra Nova' Expedition, 27 Oct 1911: 'Packed up my sketches, I am sending home ... In looking at them you must remember they were all done by artificial light – acetylene – and so they look queer by daylight – the blues and yellows are apt to go wrong.'

Wilson's task was to render in watercolour paints the scene he had viewed and committed to memory during the Antarctic daylight, aided by his sketches and notes. At night in the Winter Base Hut, his colour vision must have been fully adapted to the spectrum and luminance level of the ambient lighting, which included candles and oil lamps in addition to acetylene lamps. He therefore had to choose his colours according to both his chromatic adaptation state and the rendering of the pigments by the acetylene light.

Figure 10: *Painting illuminated by light from an acetylene flame, adapted by CIELAB*

Knowing the illumination spectrum and reflectance spectrum of the painting enables the tristimulus values at every point to be calculated precisely. But Wilson's adapted colour vision can be estimated only by applying a transformation that models human chromatic adaptation. A first attempt was by means of the CIELAB formula, using the inbuilt Von Kries correction for the white point (Hunt and Pointer 2011). Thus the X,Y,Z image pixel values calculated using acetylene illumination were converted to L^*,a^*,b^* values using the acetylene white point X_{WA},Y_{WA},Z_{WA} = 115.15,100,26.72, and thence to sRGB using the standard D65 white reference X_{W65},Y_{W65},Z_{W65} = 95.04,100,108.86. The resulting image (Fig. 10), when compared with the basic D65 rendering (Fig. 8), shows an overall pink cast and greater colour saturation, particularly in the blue sky and foreground shadow patches.

The next chromatic adaptation transform applied was CAT02, the first stage of the CIECAM02 colour appearance model (Li *et al* 2017), again taking as input the tristimulus values computed from the reflectance spectra when illuminated by acetylene light. Chromatic adaptation was assumed to be complete, so the adaptation factor D was set equal to 1.0. The first (input) illumination source was acetylene and the second (output) illuminant was D65. The adapted (output) tristimulus values (X_A,Y_A,Z_A) were converted directly to sRGB with D65 white point. The resulting image (Fig. 11) has a slightly pink cast but lower contrast and colour saturation than for the CIELAB rendering.

Figure 11: *Painting illuminated by light from an acetylene flame, fully adapted by CAT02*

The image was then processed by the recent CAT16 chromatic adaptation transform (Li *et al* 2017), using the same parameter values as for CAT02. In addition to a change in the cone sharpening matrix **M**, adaptation factors D_r, D_g, D_b for the three channels are calculated differently:

CAT02 $$D_r = \left(\frac{Y_{WA}}{Y_{WB}}\right) D \left(\frac{R_{WB}}{R_{WA}}\right) + 1 - D$$

CAT16 $$D_r = D\left(\frac{Y_W}{R_W}\right) + 1 - D$$

and similarly for D_g and D_b.

Figure 12: *Painting illuminated by light from an acetylene flame, fully adapted by CAT16*

The resulting image (Fig. 12) still has a pink cast in comparison with the reference D65 image (Fig. 8) and lower contrast that reduces the visibility of details in the distant hills. Also the blues in the sky and foreground ice sheets (lower left) are significantly reduced in colour saturation.

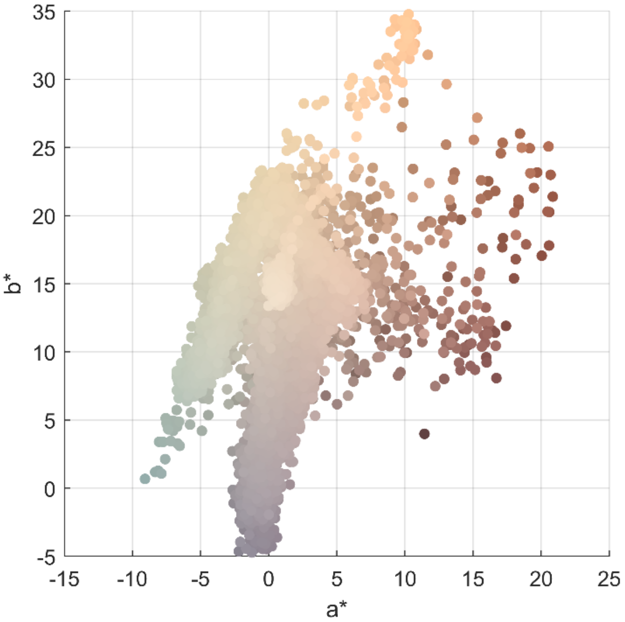

Figure 13: *Distribution of 10,000 pixels in a*-b* plane*

The distribution of colours in the D65 image (Fig. 8) is shown by scatter-plotting 10,000 randomly selected pixels within the rectangular area of the painting (i.e. excluding the mount). Fig. 13 shows that the colour gamut is rather small, with the majority of colours lying within the bounds $56 < L^* < 91$, $-7 < a^* < +8$, $-5 < b^* < +24$. The effect of the three chromatic adaptation algorithms on the mean colour of the image is compared in Table 1.

Table 1: *Image mean after chromatic adaptation*

	*L**	*a**	*b**	ΔE^*_{ab}
D65 (ref)	*78.53*	*-0.05*	*12.32*	*0*
CIELAB	*79.39*	*4.28*	*12.18*	*4.42*
CAT02	*78.85*	*2.43*	*10.59*	*3.05*
CAT16	*79.39*	*2.27*	*10.68*	*2.97*

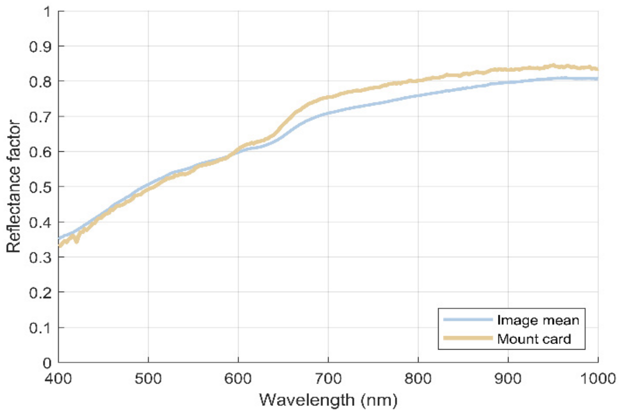

Figure 14: *Reflectance spectra of image mean and mount card over all hyperspectral image bands*

For comparison, the card in which the painting is mounted is not neutral but rather yellowish-beige, with CIELAB coordinates L^*,a^*,b^* = 79.4,1.8,14.3. Taking the mean over an 11x11 pixel region in the mount and plotting for all 270 hyperspectral bands shows the reflectance factor increasing steadily with wavelength (Fig. 14). In this case the reflectance spectrum of the mount is quite close to the mean image spectrum, and hence the effect of the chromatic adaptation algorithms is similar. The mount is important visually because it surrounds the picture and so contributes significantly to the observer's perception of its colour appearance.

5. DISCUSSION

This study commenced with the question: What did Wilson see when painting his pictures under acetylene gas light? There is no simple answer because it depends on two unknowns: his colour vision and the spectrum of the illumination.

First we may suppose that Wilson had normal colour vision, meaning that he was not colour deficient. But everyone is slightly different in colour sensitivity; the so-called Standard Observer is an average across the population of normal observers and is a convenience for computation and standardisation. So we may adopt either the older CIE 1931 Observer or the recent CIE 2015 Observer and use the corresponding colour matching functions for calculation, but there is no guarantee that either would apply exactly to Wilson.

Figure 15: *Remains of acetylene table lamp (top right) on the biology bench in the winter base hut at Cape Evans. NZ Antarctic Heritage Trust ref AHT2018-19_LM*

Second we cannot be certain about the physical construction of the acetylene desk lamps in the winter hut and the spectrum of the light they produced. We have some idea from photographs of the hut and components that survive. For example, the remains of the shade and base of the table lamp shown in Fig. 2 are still there amongst all the scientific apparatus (Fig. 15).

The lamps in the winter hut were supplied by the communal acetylene gas generator. They had no additional oxygen supply, and so they were burning with only the oxygen available in the Antarctic atmosphere at the ambient temperature within the hut. The flame depended primarily on the pressure of the gas supply and the type of burner used.

Figure 16: *(left) Remains of gas pipe and acetylene burner from the winter base hut at Cape Evans, NZ Antarctic Heritage Trust ref. AHT6509.9; (right) Bray 'Luta' gas burner*

Photographs of the apparatus give an indication of the burner (Fig. 16), which appears to be of the patented 'Luta' design (Bray 1903) with two arms arranged so that the flames from the inward-pointing jets coalesce to form a single brighter flame. The arms have tips made from steatite (soapstone) which has low thermal conductivity and remains unaffected by the heat of the flame.

Despite the uncertainty about the spectrum of the illumination, however, we do have Wilson's superb paintings, and the ability to inspect and measure them. Hyperspectral imaging enables us to obtain an accurate reflectance spectrum at every point of the painting, and hence provides the basis for more precise spectral computation, instead of the conventional trichromatic calculation.

What remains less certain is the nature of the visual adaptation of a human observer under a change of illumination. Wilson viewed the outdoor scenes under the Antarctic daylight conditions, then later he painted indoors under acetylene gas light. He was relying not only on his memory and notes but also on his perception of the pigment colours to match the coloration of the scene.

The provenance of the watercolour paints is similarly complicated. Although Winsor & Newton were official suppliers of artists materials to both of Scott's Antarctic expeditions, various watercolour manufacturers have been connected to the work of E.A. Wilson. The current location (March 2024) of the paint box visible in Ponting's flashlight photograph of Wilson working on a watercolour in 1911 (Fig. 2) is uncertain. Furthermore, 'the small selection of paint tubes, paint mixing dishes, paint brushes, and a box of coloured pastels', which remain at Cape Evans, are 'highly likely […] Ross Sea Party items (1915-17).'

Following Wilson's death in 1912, his belongings were returned to his family. In 2009, the Canterbury Museum in New Zealand acquired a wooden paint box from the estate of Wilson's sister and fellow artist, Ida Elinor Wilson. The box is marked 'Ackermann & Co. Manufacturers of Superfine Water Colours to Her Majesty' in reference to Queen Victoria who died in 1901, which places its manufacture prior to departure of the 'Discovery'. However, the pans of watercolour paint are loose in the box and made by different companies, indicating a process of continual use as a working set of artist's paints. The box includes numerous blocks of yellow, red, and blue paint, which use a variety of recipes and pigments from different geographical locations:

- Three pans of yellow paint, including: Chenel Paris, R. Ackermann 'Indian yellow'; Newton 'Chrome yellow' and numerous pans of 'Raw sienna' by R. Ackermann and Reeves & Sons.
- Two types of blue: R. Ackermann 'Antwerp blue' and 'Indigo'.
- Nine variations of red paint: Winsor & Newton 'Venetian red', 'Indian red' and 'Rose madder'; Sherborn & Tillyer 'Crimson lake'; R. Ackermann 'Crimson lake', 'Saturn red', 'Vermillion' and 'Light red'; Reeves & Woodyer 'Red chalk'.

The watercolour paintings, completed by Wilson on board the 'Discovery' 1901–03 and at Cape Evans 1910–12, were influenced by both a global trade in pigments and the connection noted by Scott between labour, light and morale. Viewed under the light of the acetylene gas lamp, with the colours filtered through layers of coal dust and soot, Wilson's paintings carry the traces of industrial processes and empire, which can also be noted in the colour names of the paints used to negotiate the 'seemingly endless white dullness' of the Arctic coastlines that were considered problematic to the public presentation of expedition photography (Iversen 2018). Wilson had planned to exhibit his watercolours alongside Ponting's black-and-white photographs as a way of conveying the hues of refraction by ice to a viewing public on his return to Britain (Wilson 1911).

Wilson was working in multiple media through profoundly harsh conditions and he left a vivid visual record documenting the polar environment. How might we address the complexity of materials and environmental conditions that he encountered in Antarctica in the early 1900s? If he had been using combinations of similar-coloured pigments from different manufacturers, or even different batches from the same manufacturer, there might have been differences in their absorption spectra. This could have resulted in metamerism, i.e. the phenomenon whereby an observer may see two pigments as appearing the same under one source of light but different under another with a different spectrum. For example, working under the acetylene lamp Wilson might have seen 'Madder rose' and 'Madder lake' as being identical, but when the paintings are later viewed under daylight the two pigments may look different. A recent study of madder entries of the company's book P1 in the Winsor & Newton 19th Century Archive found systematic differences in pigment colour, depending on the extraction process (Fig. 17). The successful preparation of a historically accurate rose madder pigment was analytically validated against a 19th-century oil paint tube of W&N Rose Madder (Veiga *et al* 2023).

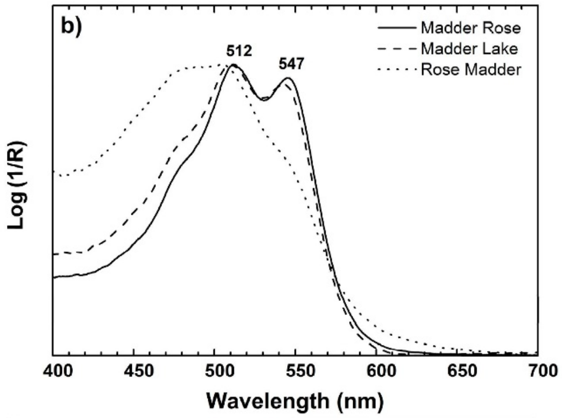

Figure 17: *Measured absorbance spectra for three W&N madder pigments (from Viega et al 2023)*

Chromatic adaptation transforms (CATs) attempt to model the effect of a change in tristimulus values from a scene viewed under a source illuminant to those under a destination illuminant. But despite more than a century of investigation, chromatic adaptation remains an unsolved research problem. In this study three common transforms were tested and produced somewhat different results. Who can say which might be nearest to what Wilson saw? The most recent model, CAT16, does reduce the distinction between blues and yellows (Fig. 12), albeit with the underlying complexity of a variety of pigments, perhaps explaining Wilson's comment that "the blues and yellows are apt to go wrong".

Finally it is worth noting that, for a professional artist, the colour memory of actual live scenes might compensate for chromatic bias due to lighting systems. Colour is a psychological affect, as shown by many chromatic optical illusions, and the colour perception of experienced professionals may be well away from average responses of the Standard Observer. Because the artist had a fixed supply of paint with known characteristics, it is quite possible that when viewing the live scene the colours of the landscapes (or snowscapes?) were remembered as pigment shades, and that memory was later applied to guide the painting process. This is a topic for further research.

6. ACKNOWLEDGEMENTS

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