

Ultraviolet and Infrared Examination of Japanese Woodblock Prints: Identifying Reds and Blues

ABSTRACT

Conservators and scholars long have been interested in understanding the traditional color palette of Japanese woodblock prints. Some of the traditional organic colorants are very difficult to distinguish visually, particularly if faded or decolorized. For decades ultraviolet and infrared examination of colorants in oil paintings have served as powerfully revealing tools. Ultraviolet light has sometimes been used to examine Japanese woodblock prints as well. This research focuses on differentiating non-synthetic reds and the three main blues employed in traditional Japanese woodblock prints produced in Edo between 1740 and 1890, using combined observations of daylight-fluorescent, ultraviolet, and infrared examination.

The twenty-three prints under study belong to the Library of Congress, Prints and Photographs Division. As part of this research project, Sandra Connors and Paul Whitmore, of the Research Center on the Materials of the Artist and the Conservator at Carnegie Mellon University, measured the light fugitiveness of the print colors using a micro-fading tester. This instrument also produced reflectance spectra that were useful in identifying safflower red, vermilion, indigo blue, dayflower blue, and through a process of elimination, Prussian blue. The instrumental data for reds and blues in each print was correlated to visual examination of the prints in daylight-balanced fluorescent lighting, recorded using Munsell color chips, and examination under long wave ultraviolet light and with an infrared video camera.

The resulting characterization of these colorants using ultraviolet and infrared radiation, both “low-tech” resources, will enable scholars and conservators to more

easily assess historic and artistic trends in the Japanese woodblock palette.

INTRODUCTION

One of the most engaging aspects of Japanese woodblock prints is their nuanced color. Fade testing of these colorants in the past two decades has shown that many are very fugitive to light. Identifying the most sensitive colorants can help custodians of collections better protect the prints when displayed. Some of the organic colorants are very difficult to distinguish visually, particularly if faded. Research by Connors and Whitmore suggests that well preserved and poorly preserved areas of the same colorants have similar fading rates. Therefore, it is likely that even a faded print will experience further colorant loss from extended display.

For decades, ultraviolet and infrared examinations of colorants in oil paintings have served as powerfully revealing tools. Ultraviolet light has sometimes been used to examine Japanese woodblock prints as well. Using these “low-tech” means of identifying colorants in what are referred to as *Ukiyo-e* prints (translated, “images of the floating world”) can aid in the preservation and technical appreciation of this art form. Being able to reconstruct the true coloring of faded prints can assist in the interpretation of the imagery and artist’s intent.

This is a preliminary report on observations of traditional, full color, Japanese woodblock prints, from Edo (now Tokyo), using combined daylight-fluorescent, ultraviolet, and infrared examination techniques to differentiate reds and blues in various saturations and conditions. The ultraviolet and infrared examination results are correlated to color identifications using reflectance spectra gathered from a micro-fading tester. The prints examined date from between 1740 to 1890, a period representing all the traditional colors. Synthetic aniline dyes are excluded from the study.

Presented at the Book & Paper Group Session, AIC 32nd Annual Meeting, June 9–14, 2004, Portland, Oregon. Received for publication Fall 2004. Color images for this paper are available online at <http://aic.stanford.edu/bpg/annual/>.

Table 1. The seventeen Edo artists whose work was included in the twenty-three prints studied

<i>Shunko</i> 1743–1812	<i>Kuniyasu</i> active 1794–1832
<i>Shigemasa</i> 1739–1820	<i>Kuniyoshi</i> 1798–1861
<i>Enkyo</i> 1749–1803	<i>Hidenobu</i> active 1805–1825
<i>Utamaro</i> 1754–1805	<i>Kunichika</i> 1835–1900
<i>Koryusai</i> active 1764–1788	<i>Kuniteru</i> 1808–1873
<i>Hokusai</i> 1760–1849	<i>Sadahide</i> 1807–1873
<i>Eizan</i> 1787–1867	<i>Yoshiiku</i> 1833–1904
<i>Hiroshige</i> 1797–1858	<i>Yoshitoshi</i> 1839–1892
<i>Kunisada</i> 1786–1865	

BACKGROUND

The twenty-three prints under study were selected as representing an historical cross-section of the Library of Congress's collection that exceeds 2300 in number. This small selection was drawn from a group of one hundred treasured works that were displayed in the exhibition, *The Floating World of Ukiyo-e: Shadows, Dreams, and Substance*, held at the Library in the Fall of 2001 (Kita et al. 2001).

The selection of prints includes the work of the seventeen Edo artists listed in table 1, and spans one hundred fifty years of evolution in the palette of woodblock prints. During this period the dominance of various reds and blues shifted, and the introduction of such foreign colorants as Prussian blue often replaced other commonly used blues.

As part of this research project, Sandra Connors and Paul Whitmore, of the Research Center on the Materials of the Artist and Conservator at Carnegie Mellon University, measured the light fugitiveness of the print colors using a micro-fading tester developed by Whitmore. The micro-fading tester is a device capable of performing non-destructive accelerated fading tests on a 0.4 mm diameter area of an object. The tests identified those colors having sensitivity to exposure in visible light. The instrument also produced reflectance and fading data useful in identifying safflower red, vermilion, indigo, dayflower blue, and through a process of elimination, Prussian blue (Connors et al. 2003; Connors 2003). Characteristic spectral curves for safflower and vermilion previously were identified in a 1995 study by Susumo Shimoyama and Yasuko Noda and in a 2001 study by Marco Leona and John Winter.

Infrared examination has been employed in forensic ink analysis for much of the past century. The authoritative ink historian, Charles Ainsworth Mitchell, documented the appearance of pigments used for writing and printing inks with infrared photography in 1937. Of those inks relevant to Japanese printmaking, he found that Prussian blue appears dark (absorbs), but indigo appears transparent. He

further noted that scarlet lake (cochineal), vermilion, and red lake appear transparent (Mitchell 1937).

As early as 1963, Charles Bridgman and Lou Gibson explored the photography of infrared emission, or luminescence, excited by blue-green light, as applied to the examination of oil paintings. Like Mitchell, Bridgman and Gibson observed that Prussian blue absorbs infrared radiation (Bridgman and Gibson 1963).

The idea of viewing Japanese prints under ultraviolet light is not a new one. A 1984 study of Japanese prints by Robert Feller and colleagues noted the ultraviolet fluorescence of safflower as well as Japanese madder, which was thought to be caused by their carthamin and purpurin and/or pseudopurpurin content respectively (Feller et al. 1984). In 1989, the Japanese print collector and historian, Rochelle Wexler Bickford, found that Prussian blue, under a "black light," appears as a bright blue color, while the other blues do not (Bickford 1989).

In one further study of fluorescence induced by ultraviolet light, Rene de la Rie notes that Prussian blue lacks, or shows very weak, fluorescence. Additionally he observed that purpurin fluoresced when combined on a paper support, in an inorganic base such as aluminum hydroxide, or with a solvent such as ethanol, acetone, and ethyl ether (de la Rie 1982).

J. Rutherford Gettens and George Stout state that the presence of purpurin causes madder lake to fluoresce a fiery yellow-red in ultraviolet light (Gettens and Stout, 1966). Finally, in *Artists' Pigments*, Feller mentions that in ultraviolet light purpurin-containing madder lake fluoresces a dull orange, cochineal fluoresces a vivid pink, lac lake does not fluoresce at all, and red lead absorbs strongly (Feller 1986–93).

EXPERIMENTAL

Ultraviolet examination was performed with a Spectroline, hand-held, 365 nanometer, long wave ultraviolet lamp. A selected vocabulary was chosen to describe the color appearance observed in the prints, or the relative fluorescence versus absorption. The descriptors include

bright “day-glow” orange, orange, pale orange, dark orange, pale pink, bright pink, maroon, dark red, mauve, light brown, dark brown, gray, warm gray, blue gray, medium blue, and purple blue.

For infrared examination, a Doya Infrared Video Analyzer was used, comprised of a silicon-enhanced diode tube with six interchangeable barrier filters on its lens. The barrier filters have a total range from 690 to 1500 nanometers. For this experiment a number 10 filter was employed for a range of 690 to 740 nanometers. Two quartz lamps were used, one with a blue-green filter with excitation from 690 to 740 nanometers, and the other a yellow filter with excitation from 490 to 600 nanometers. Lamps comprised of light in the blue-green and yellow regions of the electromagnetic spectrum are found to induce emission of red, near red, and infrared in some subjects, which therefore are said to luminesce. The system includes a black and white monitor with a resolution of 800 lines per screen (fig. 1).

Luminescence encompasses both fluorescence and phosphorescence, which are differentiated simply by the duration of emission. Phosphorescence is an after-emission that persists after the excitation source has been turned off. Fluorescence refers to emission generated only while an excitation source is on. Because the duration of emission is difficult to measure, the phenomenon observed in this study is referred to by the more general term luminescence.

Colors may have one of four appearances in infrared examination: they may appear dark (absorb), gray (reflect), transparent (transmit), or brighter than the paper support (luminesce). To simplify description of appearance that was observed on the black and white monitor, the following terms were used: dark gray for absorption, medium gray for reflectance, light gray or tone close to that of the paper for transmittance, and lighter than the paper tone for luminescence. While reds generally are transparent in infrared examination, in this study infrared luminescence was found to be key, especially in identifying safflower red.

The print colorants were examined in ambient laboratory light comprised of ultraviolet-filtered, daylight-balanced fluorescent illumination, to complement ultraviolet and infrared examination. The appearance in ambient light of the reds and blues was recorded using Munsell Matte Finish color chips. The Munsell color matching was undertaken to objectively record trends in the colorants employed for the twenty-three prints and was performed at 60 footcandles and 0.4 microwatts per lumen illumination. Characterization of the reds and blues resulting from daylight-fluorescent, ultraviolet, and infrared examination was compared with the spectral identification from the micro-fading tester (tables 2–3).

Dye swatches from a Japanese dye recipe book (Yoshioka 1982) were examined in the three methods as a



Fig. 1. Doya infrared video analyzer

form of comparison for the organic reds (safflower, sapanwood, madder, and cochineal) and indigo blue, of concern in the woodblock prints. The dye samples are on silk and employ various mordants, and therefore cannot be interpreted as equivalent to the same color on paper. Colorants mordanted with alum were selected as a more appropriate comparison to the colors as they would be printed on the Japanese paper used for woodblock prints, which is surface sized with animal glue and alum. While these dye samples on silk could not function as experimental controls, their appearance was consistent with our observations on safflower and indigo. These same dye samples also were analyzed by Jennifer Giaccai, at the Freer-Sackler Gallery of Art, using reflectance spectroscopy. Their reflectance spectra were found to be fairly consistent with Giaccai's research on organic reds used in Japanese paintings of the Edo period.

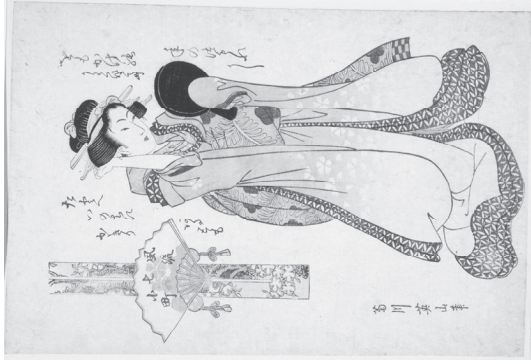
RESULTS GATHERED FROM EXAMINATION OF WOODBLOCK PRINTS

Results gathered from the examination of the woodblock prints are presented in table 2.

Inorganic red lead and vermilion have been used since the advent of hand coloring on black and white woodblock prints starting around the 1690s. The colors continued to be used in limited amounts as full color prints came into production around 1765. Intentionally induced sulfiding of red lead to create a dark grey-brown patina on red in Japanese prints is discussed in a paper by Judy Walsh, Barbara Berrie, and Michael Palmer (Walsh et al. 1997). Especially when used for architectural elements, this effect mimics the weathering seen on red painted temples and shrines, an effect that hardly seems accidental.

Of the organic reds, safflower is by far the most commonly used from around 1700 to the mid-nineteenth century. The Feller study mentions madder, but other significant references on Japanese print production, such as

Table 2. Fiske-Morenus chart comparing all analysis and observations for Eizan



Accession No. **2.01.201.56** Sandra Connors Micro-Fading 2.2.12 measured 3/28/03
 Artist: **Eizan** Blue wool delta E data for this day of testing:
 Subject: Modern Seven Komachi Blue wool #1 (Delta E = 6.17, after 5 minutes of exposure)
 Blue wool #2 (Delta E = 4.79, after 5 minutes of exposure)
 Blue wool #3 (Delta E = 0.82, after 5 minutes of exposure)

Overall Print Color Quality: Good

Collected Data (Bold indicates most sensitive color)

Measurement Name	Location on Print	Delta E after 5 minutes	Comparison to Blue Wool Standard	Colorant Identification (when possible)	Ultraviolet Appearance	Infrared Appearance	Munsell Color Chip Match
YELLOW 3	dark area on screen	3.97	2-3	0	light ochre	same as paper	0
RED 4	collar of figure's robe	1.41	2-3	BENI safflower	bright orange	lighter than paper	10R Chroma 6 Value 7
ORANGE 3	yellow/red overprint on robe	1.16	2-3	BENI safflower and yellow	tan	light gray	10R Chroma 6 Value 7
BLUE 2	decoration in top left corner	1.03	2-3	AI indigo	light gray	light gray	5B Chroma 1 Value 7
PURPLE 3	figure's robe	0.90	2-3	BENI safflower and blue	orange tan	same as paper	0
GREEN 2	blue/yellow in overprint decoration at top	1.14	2-3	AI indigo and yellow	light olive	light gray	0
GREEN 3	dark area on robe	0.47	<3	AI indigo and yellow	dark green	medium gray	0
PAPER 2	background left side of decoration	0.90	2-3				

Table 3. Sandra Connors report on micro-fading tester readings for Eizan

2.2.12 Print 2.01.201.56 by Eizan

Measurements taken on March 28, 2003

Blue wool delta E data for this day of testing:

Blue wool #1 (Delta E = 6.17, after 5 minutes of exposure)

Blue wool #2 (Delta E = 4.79, after 5 minutes of exposure)

Blue wool #3 (Delta E = 0.82, after 5 minutes of exposure)

Collected Data (bold indicates most light-sensitive color):

Measurement Name	Location on Print	Delta E after 5 Minutes	Comparison to Blue Wool Standards	Colorant Identification (when possible)
yell3	decoration at top of print	1.72	between bw2 and bw3	-
red4	collar of figure's robe	1.41	between bw2 and bw3	Beni
pur3	figure's robe	0.90	between bw2 and bw3	Beni and blue
paper2	background, left side of decoration	0.90.	between bw2 and bw3	-
org3	yellow/red overprint on robe	1.16	between bw2 and bw3	Beni and yellow
grn3	dark area on robe	0.47	<bw3	Ai and yellow
grn2	blue/yellow overprint in decoration at top	1.14	between bw2 and bw3	Ai and yellow
blue2	decoration in top left corner	1.03	between bw2 and bw3	Ai

Observations:

The most light-sensitive color on this print is yellow (yell3), fading at a rate between blue wool 2 and blue wool 3. Beni was identified in areas of red (red4), purple (pur3), and orange (org3) by its spectral characteristics (i.e. absorbance peak at 540 nm and a reflectance maximum around 460 nm). Ai was also found in areas of green (grn3 and grn2) and blue (blue2) on this print. It was identified by the absorbance between 660 and 700 nm and the reflectance maximum at 750 nm, both of which are typical for Ai.

those by Ishii Kendo, Chie Hirano, or T. Tokuno, do not include it (Feller et al. 1984; Kendo 1929; Hirano 1939; Morse 1982). Sappanwood is mentioned in all the above references. A color chronology by Roger and Keiko Keyes, used in their workshops on woodblock prints given at the Allen Art Museum in Oberlin during the late 1980s, shows sappanwood as a color introduced after 1825. Feller suggests that cochineal was imported from China and used in place of safflower in later prints (Feller et al. 1984). However, the extent of use of madder, sappanwood, and cochineal in woodblock prints needs to be confirmed by further analysis.

As noted from literature sources, vermilion is not expected to fluoresce, but rather to absorb in ultraviolet

and to transmit, or be nearly transparent, under infrared examination. In a beautifully printed, privately commissioned *surimono* by Hidenobu (ca. 1820), there is an example of a scarlet color identified by Connors as not inconsistent with vermilion. In ultraviolet light it reads as dark red and in infrared examination it reads as a light gray tone, transmitting most infrared radiation (fig. 2). (While the color areas discussed in the prints are not obvious in black and white reproduction, the images are included as a point of reference.)

The important collector's seals found on prints are hand stamped with the typical vermilion ink used in Japan. These stamps also appear as dark red in ultraviolet light. As noted by Mitchell, vermilion is barely visible with infrared

Table 4. Preliminary finding on appearance of reds in woodblock prints and of colorants painted on paper

	Colorant	Visible Light	Ultraviolet	Infrared Video
Inorganic	Vermilion Mercuric sulfide	Dark red	Absorbs	Transmits, appears same or lighter than paper
	Red Lead* Lead tetraoxide	Orange-red	Absorbs	Absorbs, appears dark gray
Organic	Benibana Safflower Carthamus tinctorius	Pink to red	Fluoresces bright “day-glow” orange	Luminesces strongly, appears brighter than paper
	Akane* Madder Rubia cordifolia	Red	Fluoresces yellow-red	Inconclusive
	Suo* Sappan wood Caesalpinia sappan	Reddish-lavender (mordanted with potash) Orangish-red (mordanted with alum)	Fluoresces mauve Fluoresces orange-pink	Luminesces strongly, appears brighter than paper Luminesces brighter than paper but less than above
	Enji* Cochineal Coccus cacti	Purple-red	Fluoresces pink	Inconclusive

*No definitive example of colorant identified by Connors with the micro-fading tester.



Fig. 2. Hidenobu (ca. 1820), *Hair Ornaments and Toilet Articles* (2.01.201.59)

examination, as was the case with the vermilion stamps observed in this study. In contrast, the orange-red inside the bowl, in the Hidenobu *surimono* mentioned earlier, is a safflower red which has a characteristic fluorescence in ultraviolet light, except where overprinted with black in the shadow of the bowl.

In the large figure of the left panel of a Kuniyoshi triptych (1850), the absorption of a red lead in ultraviolet light is evident. Under infrared examination the red lead reads as a medium gray tone. Again, as a contrast, the pale pink flesh color in the right figure of the middle panel is safflower that faintly fluoresces in ultraviolet, and luminesces brightly when viewed with the infrared video camera (figs. 3–4).

We can speculate that the light-sensitive colors in a large number of *Ukiyo-e* prints have faded to some degree over their 250 to 300-year life. It can sometimes seem shocking then to see the bright, saturated colors in prints that have been relatively protected. Particularly reds and purples can seem almost garish. However, visually the overall palette comes into harmony when all colors are fully saturated, rather than the imbalance that occurs when unfaded colors overwhelm those that are faded. Often the most intense colors can be seen in *shunga*, the erotic prints that probably have seen little display.

The print by Kunitaru (1867) is a good example of the tell-tale fluorescence of safflower in ultraviolet and its luminescence when examined with the infrared video camera. In this print, both the darker and lighter reds, and the



Fig. 3. Kuniyoshi (1850), left panel, *The Famous Unrivaled Hidari Jinoro* (2.01.201.71A)



Fig. 4. Kuniyoshi (1850), middle panel, *Sculptor and Gods* (2.01.201.71B)

orange made of red mixed with yellow, have the characteristics of safflower when examined with these methods (fig. 5).

Compared to the previous print by Kuniteru, the Eizan (1800–1867) color palette is slightly less saturated. Yet the red, spectrally identified as safflower, fluoresces under ultraviolet, and the orange, which is a mixture of safflower and yellow, has some fluorescence as well. In infrared examination the luminescence of safflower clearly can be seen, making the paper tone appear darker than the area printed with red safflower (fig. 6).

Compared to the Eizan, the two colors in the kimono and cap of a print by Enkyo (1796) appear more faded. Examined with the infrared video camera, the pink luminesces and the purple appears slightly brighter than the paper tone. As with the orange in the last example, we see that the purple, a mix of red and blue, still exhibits the characteristics of the safflower component (fig. 7).

The Shunko (1760) exhibits even more fading, yet the safflower does fluoresce in ultraviolet light. It also presents the infrared luminescence seen in the previous examples of more saturated safflower, reading as slightly brighter than the paper tone (fig. 8).

These examples illustrate the potential for this method to help scholars interpret the original appearance of *Ukiyo-e* print colors, and to assist a collection custodian in identifying sensitive colors in order to better assess the risk to the print of further exposure to light.



Fig. 5. Kuniteru (1867), *Famous Places in Edo: Ai no Uchi* (2.01.021.92)



Fig. 6. Eizan (1800–1867), *Modern Seven Komachi* (2.01.201.56)

For centuries dayflower blue has been used in Japan to make an under-drawing on silk as a guide for painting or for applying stop-out for resist dyeing. It is a colorant that will completely wash out in water, and because of its solubility in water, dayflower is not generally used as a textile dye. Woodblock printers were surely aware of this sensitivity to moisture, particularly as they printed on dampened paper. Also, dayflower does not make an intense blue but rather a translucent cool or grayish-blue.

The use of dayflower blue seems to occur more in the early years of color printing, being largely replaced by indigo in the late eighteenth century. A study by Shiho Sasaki and Pauline Weber explores the manufacture and properties of this color thoroughly (Sasaki and Weber 2002).

Indigo is a staple of Japanese textile dyeing and is grown in southern Japan. It has been used in prints from the beginning of color printing through the nineteenth century.

Prussian blue, first available in Europe in 1704, was known to have been imported into Nagasaki in the 1820s, and was used extensively by Hokusai in his print series *Thirty-six Views of Mount Fuji*. Recent study by Roger Keyes and Elizabeth Coombs suggests that Prussian blue was used in the late eighteenth century (Keyes and Coombs 2002).

In a delicately printed *surimono* by Kuniyasu (ca. 1810–20), dayflower blue is used in the robe and mixed with yellow to make a pale green in the hat. This is the only example of dayflower spectrally identified by Connors. Dayflower, appropriate to its sensitivity to moisture, makes



Fig. 7. Enkyo (1796), *Portrait of Nakayama Tomisaburo* (2.01.201.20)



Fig. 8. Shunko (1760), *Danjuro in Thunder God Pose* (2.01.201.12)



Fig. 9. Kuniyasu (ca. 1810–20), *Man and Bonsai* (8.2000.804.92)



Fig. 10. Kuniyasu (ca. 1810–20), *Man and Bonsai* (8.2000.804.92), under infrared light.

a translucent, sometimes watery-looking blue. In ultraviolet it is a warm, light to medium gray. Examined with the infrared video camera it appears as a light gray tone or almost the same as paper tone (figs. 9–10). Although not evident in this undamaged print, dayflower sometimes has a drippy, mottled appearance where humidity or contact with moisture has caused the color to move or dissipate. This form of damage generally is not seen in indigo or Prussian blue.

In ambient light, indigo can have a cool greenish or bluish-gray appearance. It also can be applied thinly and vary greatly in saturation. Indigo is usually the color used to mix with or overprint yellow to create green.

In consulting a triptych by Yoshiku (1860), using both ultraviolet and infrared examination, the area of the water, spectrally identified as indigo, appears light to medium gray using either techniques. In the left kimono of the left panel, the contrasting appearance of the spectrally identified colorants, indigo (medium blue) and Prussian blue (dark blue), is patently evident in both ultraviolet and infrared examination as well (fig. 11).

As mentioned in several literature sources, the iron in Prussian blue makes it absorb under infrared examination, appearing moderately dark gray in tone, depending on its saturation. Dayflower and indigo appear light gray under the same viewing conditions. Under ultraviolet, Prussian blue appears bright blue versus the more subdued grays



Fig. 11. Yoshiku (1860), left panel, *Drinking Party Among People of Five Countries at Gankyo Tea House* (2.01.201.84A)



Fig. 12. Hiroshige (1856–59), *Distant View of Kinryusan from Azuma Bridge* (2.01.201.29)

for which the dayflower and indigo are notable. These observations are exemplified by the two prints by Hiroshige (1856–59) (figs. 12–13).

SUMMARY

The comparison between the spectral identifications for reds provided by the micro-fading tester and appearance in ultraviolet and infrared examination are summarized in table 4. All of the reds spectrally identified as safflower were consistent in UV fluorescence and luminescence when viewed with the infrared video camera. The two colors identified as vermilion were also consistent in their appearance under ultraviolet and infrared examination.

Thirty colors were unidentified by spectra. Not all of these could be categorized according to their appearance using ultraviolet and infrared examination. However, of these thirty unidentified reds, the paired pattern of appearance under ultraviolet and infrared examination strongly suggests an identification for an additional six safflower and three vermilion examples.

Five of the prints examined exhibited a distinctive mauve color in ultraviolet light. Infrared examination shows a fairly consistent reflectance in a light gray tone. None of these pinkish colors were spectrally identified by

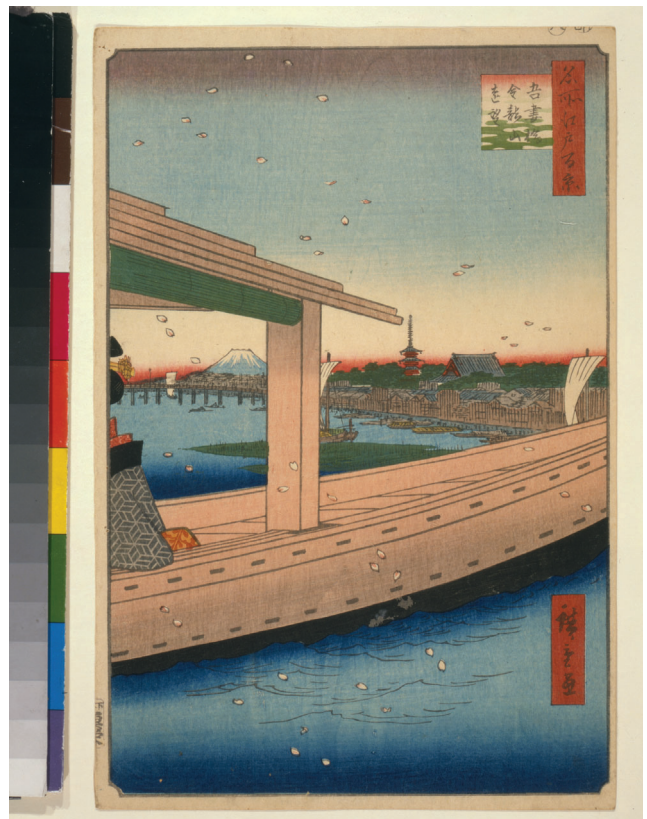


Fig. 13. Hiroshige (1856–59), *Senju Ohashi* (2.01.201.30)

Connors. More research needs to be done on identifying the use of sappanwood, madder, and cochineal in Japanese woodblock prints.

The comparison between spectral identifications for blues provided by the micro-fading tester and appearance in ultraviolet and infrared examination is summarized in table 5. All of the blues identified as Prussian blue were consistent in ultraviolet light and when viewed with the infrared video camera. The four colors identified as indigo also were consistent using this paired examination method.

Using the ultraviolet and infrared examination results for the one color spectrally identified as dayflower made it possible, using ultraviolet and infrared examination, to suggest that three more unidentified colors are possibly dayflower. However, indigo and dayflower can be difficult to differentiate. Here the discernable difference between these two blues seen in visible light also must be considered.

It is anticipated that a clearer pattern will emerge in the next phase of this investigation, during which the red, blue, as well as yellow colorants will be prepared from natural dye stuffs, printed onto a Japanese printing paper, artificially aged, and observed using the daylight-fluorescent, ultraviolet, and infrared examination methods described.

Table 5. Preliminary findings on appearance of blues in woodblock prints and of colorants painted on paper

	Colorant	Visible Light	Ultraviolet	Infrared Video
Inorganic	<i>Bero-ai</i> Prussian Blue Ferric ferrocyanide	Dark to light blue	Appears dark to medium blue	Appears dark gray
Organic	<i>Ai</i> Indigo Polygonum tinctorium	Greenish-blue	Appears light to medium blue-gray	Appears light gray
	<i>Aobana</i> Dayflower Commelina communis	Translucent cool or grayish-blue	Appears warm light to medium gray or blue-gray	Appears light gray

Table 6. Summary of reds

66 Micro-Fading Tester Readings	Viewed in Long Wave Ultraviolet Light	Viewed by Infrared Video	
34 Safflower red	34 Fluoresce orange	34 Luminescent	
2 Vermilion	2 Dark red brown	2 Medium grey	
30 Unidentified	6 Fluoresce orange	6 Close to paper	
	3 Dark red brown	3 Medium grey	
	5 Mauve		4 Light grey
			1 Same as paper
	4 Light brown	3 Light grey	
	1 Same as paper		

Table 7. Summary of blues

29 Micro-Fading Tester Readings	Viewed by Long Wave Ultraviolet Light	Viewed by Infrared Video
19 Prussian blue	19 Medium dark blue	19 Medium dark grey
4 Indigo	4 Light grey	4 Light to medium grey
1 Dayflower	1 Light grey	1 Light grey
5 Unidentified	2 Warm grey	1 Light grey
		1 Medium grey
	1 Light grey	1 Light grey
	1 Ochre grey	1 Light grey
	1 Indistinct	1 Medium grey

CONCLUSIONS

- Reflectance spectroscopy is useful in identifying many organic and inorganic colors used in Japanese woodblock prints.
- Ultraviolet and infrared examination can be applied to identify several Ukiyo-e colors with moderate reliability:
- Vermilion, red lead, safflower red.
- Prussian blue, indigo, dayflower blue.
- Ultraviolet and infrared examination also can help identify faded colors.

ACKNOWLEDGMENTS

We thank all of our colleagues listed here for their valuable support and assistance.

Katherine Blood, Curator, Prints and Photographs Division, Library of Congress

Dianne van der Reyden, Chief, Conservation Division, Library of Congress

Maria Nugent, Head, Book and Paper Conservation Section, Library of Congress

Marita Clance and Michael Horsley, Conservation Photographers, Library of Congress

Sandra Connors, Scientist and Paul Whitmore, Director,
Research Center on the Materials of the Artist and
Conservator, Carnegie Mellon University
Jennifer Giaccai, Scientist, Freer-Sackler Gallery of Art
Carole Zimmerman, Librarian, Conservation Division,
Library of Congress

REFERENCES

- Bickford, Rochelle Wexler. 1989. Identification of Prussian Blue. *Andon* 9(2) [issue no. 34].
- Bridgman, Charles, and Lou Gibson. 1963. Infrared luminescence in the photographic examination of paintings and other art objects. *Studies in Conservation* 8(3):77–83.
- Connors, Sandra A., Paul Whitmore, Roger Keyes, and Elizabeth I. Coombs. 2003. The identification and light sensitivity of Japanese woodblock print colorants: the impact on art history and preservation. Paper presented at the Second Forbes Symposium, Freer Gallery of Art, September 2003. Not yet published.
- Connors, Sandra A. 2003. Report to the Library of Congress on the light testing of twenty-three Japanese woodblock prints from the 18th and 19th centuries. Library of Congress, Conservation Division, May 2003. Unpublished report.
- de la Rie, Rene. 1982. Fluorescence of paint and varnish layers, Part I. *Studies in Conservation* 27(1):1–7.
- Facini, Michelle. 2002. Seeing red: Investigating Japanese woodblock prints and organic colorants using spectrophotometry. *Papers presented at the twenty-seventh annual conference of the Association of North American Graduate Programs in the Conservation of Cultural Property (ANAG-PIC), April 19–21, 2001*. Newark, DE: Winterthur/University of Delaware.
- Feller, Robert L., Mary Curran, and Catherine W. Bailie. 1984. Identification of traditional organic colorants employed in Japanese prints and determination of their rates of fading. *Japanese woodblock prints: A catalogue of the Mary A. Ainsworth Collection*. Oberlin, Ohio: Allen Memorial Art Museum.
- Feller, Robert L. 1986–1993. *Artists' pigments*. 3 vols. Washington: National Gallery of Art.
- Gettens, Rutherford J., and George L. Stout. 1966. *Painting materials: A short encyclopedia*. New York: Dover Publications.
- Hirano, Chie. 1939. *The making of Japanese prints and the history of Ukiyo-e. Kiyonaga: A study of his life and works*. Cambridge, Mass.; Published for the Museum of Fine Arts by the Harvard University Press.
- Kendo cho, Ishii. 1929. Nishiki-e no hori to suri: *The engraving and printing of Japanese prints*. Tokyo: Unsodo. Republished in 1994.
- Keyes, Roger S., and Elizabeth I. Coombs. 2002. *Color as language in traditional Japanese prints. The broad spectrum: Studies in the materials, techniques and conservation of color on paper*. London: Archetype Publications.
- Kita, Sandy, Lawrence Marceau, Katherine Blood, and James Douglas Farquhar. 2001. *The floating world of Ukiyo-e: Shadows, dreams, and substance*. New York, NY: Harry N. Abrams, Inc. in association with the Library of Congress.
- Leona, Marco, and John Winter. 2001. *Fiber optics reflectance spectroscopy: A unique tool for the investigation of Japanese paintings*. *Studies in Conservation* 46(3).
- Mitchell, Charles Ainsworth. 1937. *Inks, their composition and manufacture, including methods of examination and a full list of British patents*. London: Griffin & Co.
- Morse, Peter, ed. 1982. Tokuno's description of Japanese printmaking. In *Essays on Japanese art presented to Jack Hillier*, ed. Matthi Forrer. London: R. G. Sawers Publishing.
- Sasaki, Shiho, and Pauline Webber. 2002. A study of dayflower blue used in Ukiyo-e prints. In *Works of art on paper, books, documents and photographs: techniques and conservation: Contributions to the Baltimore Congress, 2–6 September 2002*. London: Institute for Conservation of Historic and Artistic Works.
- Shimoyama, Susumu, and Yasuko Noda. 1995. Non-destructive determination of plant dyestuffs used for ancient madder dyeing, employing a three-dimensional fluorescence spectrum technique. *Dyes in History and Archeology* 13.
- Shimoyama, Susumu, and Yasuko Noda. 1996. *Determination of plant dyestuffs used for traditional Japanese woodblock prints, employing a three-dimensional fluorescence spectrum technique and quartz fibre optics*. *Dyes in History and Archeology* 15.
- Walsh, Judy, Barbara Berrie, and Michael Palmer. 1998. The connoisseurship problem of discoloured lead pigments in Japanese woodblock prints. In *IPC conference papers London 1997: proceedings of the fourth International Conference of the Institute of Paper Conservation 6–9 April 1997*. Worcester, U.K.: Institute of Paper Conservation.
- Yoshioka, Tsuneo. 1982. *Simple dyes made from plants*. Kyoto, Japan: Shikibeni sha, Inc.

BETTY FISKE
Winterthur Museum
Paper Conservation Department
Wilmington, Delaware
bfiske@winterthur.org

LINDA STIBER MORENUS
Senior Paper Conservator
Library of Congress
Washington, D.C.
lsti@loc.gov